PARTITIONING OF PHOSPHORUS
IN A FLORIDA HISTOSOL

By

IAN KEITH NICHOLSON

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1983

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. J.G.A. Fiskell for the wise guidance and extreme patience that he has given me during the course of this investigation and in the preparation of this manuscript.

Gratitude is extended to Dr. D.A. Graetz, Dr. D.H. Hubbell, Dr. J.J. McCreary, Dr. G.H. Snyder, and Dr. B.G. Volk for serving on my supervisory committee.

Financial support from the Agricultural Research and Education Center, Belle Glade, Florida and the Department of Soil Science, University of Florida, is gratefully acknowledged.

Appreciation is extended to Dr. D.L. Myhre for his assistance in gathering background information.

I wish to express my sincere appreciation to Gillian Nicholson, who assisted in the laboratory and typed the manuscript. To Barbara Erin, our daughter, I wish to express thanks for making moments with her a joy.

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Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

PARTITIONING OF PHOSPHORUS IN A FLORIDA HISTOSOL

By

Ian Keith Nicholson

April 1983

Chairman: John G.A. Fiskell
Major Department: Soil Science

Partitioning of soil phosphorus (P) in Pahokee muck (a euic, hyperthermic Lithic Medisaprist), located at the Agricultural Research and Education Center, Belle Glade, Florida, was investigated at seven depths in 11 fields of varying cropping histories. The P categories were inorganic P extracted by water, double acid soil test reagent, or hot 0.1N HCl, and total P by hot 0.1N HCl or by ashing. Organic P by hot 0.1N HCl was calculated as the difference between the total and inorganic P extracted by this reagent. Total organic P was estimated by total soil P minus inorganic P by the hot acid. Residual organic P was total organic P minus organic P by the hot acid.

The variability for each P category was examined statistically where fields, depths, and fields x depths were in the model. For each category, the model explained more than 75% of the variation. Significant field x depth interactions for both categories of total P, total organic P, and organic P by the hot acid, resulted from the effects of soil tillage and P fertilization. Levels of copper, with which the Everglades Histosols are also fertilized, were strongly correlated with those of total P.

Mean values of residual organic P were significantly low in the intensively cultivated fields, but these were accompanied by high levels of organic P extractable with hot acid. Mean values of inorganic P extracted by each of the three reagents decreased with depth to 0.43 m. High mean values were found in a field used for horticulture. Inorganic P extracted by double acid was from 30 to 59% of the inorganic P extracted by the hot acid in the top 0.15 m of the cultivated fields, compared to 9% from a virgin muck. Water-extractable inorganic P accounted for 2.8 to 4.1% of the inorganic P in the same depth of the cultivated fields, compared to 13.6% in the virgin soil.

Laboratory experiments were conducted to investigate the depletion of water-soluble inorganic P added to muck samples incubated with and without corn stover, and the regeneration of water-extractable inorganic P in leached muck samples.

INTRODUCTION

Histosols are soils principally composed of humified organic matter which has accumulated under wet, poorly-drained conditions over long periods of time. After being drained and brought under cultivation, they are used mainly for vegetable production. The largest continuous area of Histosols in agricultural production, worldwide, occurs in southern Florida between Lake Okeechobee and the Everglades Conservation Area. In the early cultivation of Histosols in Florida, crop failure occurred because of copper deficiency. When this was corrected, the peat and muck soils of this area soon became major suppliers of vegetables for much of the United States during the winter months. Almost since cultivation of these soils began, phosphorus (P) fertilization has been practiced, varying in rate depending on the crop involved. Fortunately, the Agricultural Research and Education Center (AREC) at Belle Glade had the foresight to maintain fields under various continuous uses. This permits an evaluation of such land-use practices.

One of the unfortunate consequences of the agricultural use of Histosols is that much of the depth of these soils is continuously being lost by subsidence. This feature may be attributed to a number of factors including microbial decomposition, drainage, and compaction by farm equipment. These factors also might be expected to play a part in the distribution of P under various soil management practices. At present, the availability of P is measured usually by water extraction and cations by dilute acetic acid extraction. The pool of P replenishing the water-soluble fraction is not fully understood. It would be expected that the high microbial activity in these organic soils plays a major role in mineralization of both slightly soluble inorganic P, and organic P. Although mineral soils have been analyzed for organic P, such technique has not been used for the Florida Histosols. The organic P is generally assumed to be in a form that is very slowly available to agricultural crops. Although it is well known that drainage water from the area contains considerable inorganic P, which is usually less than the total P of this water, the source of this P is not well understood. The long-term soil-use studies at the AREC, Belle Glade, offer a unique opportunity to evaluate the P status of this Histosol.

The objectives of the present studies were (i) to partition the soil P in profiles from various fields into several categories, including inorganic P and organic P; and (ii) to investigate some possible factors contributing to changes in water-soluble P in this Histosol.

LITERATURE REVIEW

Peat Accumulation and Subsidence

Present peat deposits result from the balance of original peat deposition and its subsidence due to fires, drainage, and microbial oxidation processes. Studies on peat formation in the Upper Everglades, summarized by Lucas (1982), indicated that it took 800 years to produce 0.08 m of basal marly-muck and that, on this foundation, some 4,000 years of favorable plant growth resulted in a peat thickness of about 3.65 m by the year 1914. He stated that the volume production was about 8.4 m^3 ha^{-1} yr^{-1}. Davis (1946) concluded that topographic conditions favored the great accumulation of peat, with most of the vegetation providing the peat deposit being sedges, rushes, reeds, and grasses. He listed numerous plant species occurring in this area. Lucas (1982) quoted data that world organic soil resources were 342,647,000 ha, of which 1,215,000 were in Florida. Principal components of the organic matter of peat were reported by Lucas (1982) and for humic acid by Volk and Schnitzer (1973). In Pahokee muck, Zelazny and Carlisle (1974) found 57% was humin, 36% fulvic acid, and 7% humic acid, whereas corresponding fractions in Torry muck were 55, 38, and 7%, respectively.

Subsidence of Florida Histosols was studied by Stephens and Johnson (1951) and they concluded that, by the year 2000, the total volume loss in cross-sectional area would be 88%. Snyder et al. (1978) stated that these predictions were holding. Factors affecting peat subsidence were listed by Volk (1973) as drying, drainage, compaction, and oxidation (including burning), and he gave subsidence rates from carbon dioxide evolution. Browder and Volk (1978) provided a mass balance model with a microbial compartment to show the contribution of temperature, water table control, and organic carbon loss. Shih et al. (1978) introduced a model based on water table and three crop variables, and showed that subsidence rate was linearly related to the average depth of water table with probably more subsidence in fields with pasture or vegetables than in those with sugarcane (Saccharum officinarum L.). In a further study, Shih et al. (1979) investigated subsidence rates for different land-use conditions and, from regression analyses, estimated that muck depth would be 0.39 m by the year 2000. They felt that maintaining the water table depth at 0.30 m, rather than at 0.46 to 0.55 m, would delay reaching this depth of muck until the years 2029 and 2052 for truck crops and sugarcane, respectively.

Microbes in Florida Histosols

Waksman and Stevens (1929) investigated the occurrence of microorganisms in 1 g-samples of soil from the 0 to 0.26 m, 0.26 to 0.40 m, 0.50 to 0.62 m, and 1.10 to 1.20 m depths of a lowmoor peat profile from the Everglades. Corresponding pH and moisture contents were 6.2 and 66.8%, 6.4 and 71.4%, 6.5 and 85.0%, and 6.3 and 83.4%, respectively. They reported that the total number of bacteria (both aerobic and facultative anaerobic) and actinomycetes was 9.6×10^6, 32.8×10^6, 3.0×10^6, and 1.6×10^6 at the surface, 0.26 to 0.40 m, 0.50 to 0.62 m, and 1.10 to 1.20 m depths, respectively. Corresponding estimates of the number of fungi were 2.6×10^4, 2.0×10^4, 0, and 0. The abundance of actinomycetes was expressed as a percentage of the total number of bacteria and actinomycetes. The values were 35, 22, 23, and 0% for the repective depths. In the same study, the authors qualitatively appraised the occurrence of cellulose-decomposing, nitrifying, and anaerobic bacteria. Population density was classed as "a few," "a fair number," "an abundance," and "numerous" (2.5×10^4 or more colonies formed by 1 g of soil). They reported that a fair number of cellulose-decomposing bacteria occurred in the three top depths of soil studied and that a few occurred in the 1.10 to 1.20 m depth. They detected an abundance of nitrifying bacteria in the surface depth, a fair number in the 0.26 to 0.40 m and 0.50 to 0.62 m depths, and a few in the lowest depth. The authors noted, however, a few anaerobic bacteria in the surface depth, a fair number in the 0.26 to 0.40 m and 0.50 to 0.62 m depths, and an abundance in the 1.10 to 1.20 m depth.

Waksman and Stevens (1929) also studied the effect of several treatments on carbon dioxide evolution from a fresh lowmoor peat and found that carbon dioxide evolved was increased by about 15% with the addition of either cow manure or a fertilizer, and about 300% or more by cellulose or rye (Secale cereale L.) straw incorporation. The latter treatments reduced the total nitrogen liberated. They stated that the organic complexes in peat are very resistant to decomposition. They also determined that addition of ammonium sulfate did not change the amount of carbon dioxide evolved in 20 days.

Terry (1980) reported that carbon dioxide evolution from Terra Ceia soil, cropped to sugarcane, was higher than from uncropped Pahokee and Lauderhill soils, and least for Torry soil. Although the latter was cropped to sweetcorn (Zea mays L. rugosa), it had the lowest content of organic carbon (14.4% compared to about 43% for the other three soils). Terry (1980) also noted that addition of glucose or grass clippings greatly enhanced the carbon dioxide evolution from Pahokee muck.

Tate (1979) used succinate as a convenient indicator of soil respiration and found that the effect of crop on carbon metabolism in Pahokee muck was significant. He used five ^{14}C-labeled substrates in a study on the effect of soil depths on carbon metabolism and found the highest activities at the 0 to 0.10 m depth for succinate, but other sources resulted in much lower carbon dioxide evolution at all depths compared to that of succinate.

Duxbury and Tate (1981) studied the activities of acid phosphatase, invertase, cellulase, xylanase, amylase, peroxidase, and polyphenol oxidase in Pahokee muck soil with different crop histories. They concluded that none of the measured enzymatic activities could be conclusively related to the decomposition of native soil organic matter compared to that of fresh residues. They noted that fallow soil exhibited much lower activities of hydrolytic enzymes than those under sugarcane or grasses. This suggested that some of the enzymatic activity could be associated with root exudates.

Comprehensive reviews of microbial activity in Histosols were given by Tate (1980) and Given and Dickinson (1975). Facets of microbial activity other than those discussed were compiled by Waksman (1952).

Blue-green Algae of the Florida Everglades

Gleason (1974) compiled a series of papers on the early exploration, the predrainage hydrology, and the ecology of the Florida

Everglades. They reported the distribution of 36 genera of blue-green algae in the periphytin and the benthos in a study conducted during the period 1964 to 1974. These authors noted that there was a wide range of phosphate concentrations in the water and attributed this to seasonal changes and, in the sinkholes, to mass mortality of fish during droughts and the release of large quantities of hydrogen sulfide. They stated that this phosphate release was important in producing the algal blooms when the water level rises. Furthermore, they mentioned that it is well documented that blue-green algae are important agents in dissolving and precipitating calcium carbonate, presumably by changing the pH by photosynthesis and respiration. Alexander (1977) noted that the nitrogen-fixing ability of blue-green algae has long been recognized in flooded rice paddies. He reported a specific study in culture media of Azotobacter vinelandii and the blue-green algae Cylindrospermum cylindrica where nitrogen fixed was 1,050 and 52 mg $N.L^{-1}$, respectively.

Change in Histosol Composition

Using the soil classification system then in vogue, Hammar (1929) observed that the nitrogen content range for custard apple, elderberry, and sawgrass Everglades soils was 1.1 to 1.9%, 2.1 to 3.1%, and 2.5 to 3.0%, respectively. Comparable phosphorus content ranged from 0.08 to 0.35% , 0.10 to 0.26%, and 0.09 to 0.34%, respectively. This showed that there was a wide range in both nitrogen and phosphorus content of these soils. He also found a much higher aluminum content in the custard apple soil than in the other two soils. He stated that there was quite variable and irregular ash content at different depths in the same soil type. The loss on ignition of custard apple soil averaged 44% compared to 80% and 87% for the elderberry and sawgrass soils, respectively. In a sampling by Caldwell (1941) made 13 years later, samples from custard apple soil averaged 58% loss on ignition to 0.66 m depth compared to a loss of 81% at similar depths of sawgrass soil. In samples of Histosols obtained by Zelazny and Carlisle (1974) from sugarcane fields, loss on ignition of Pahokee (probably sawgrass in older classification) was 84% compared to 32% for Torry soil (formerly classed as custard apple soil). Terry (1980) determined 84% loss on ignition for Pahokee soil compared to 35% in Torry soil. Volk and Schnitzer (1973) determined that Pahokee soil contained 3.2% N compared to a mean value of 2.2% N given by Terry (1980) for this soil. There was no indication that these samples were from the same site.

Phosphorus Fertilization of Histosols

One of the better studies on phosphorus requirements of crops in the Everglades was the work of Neller (1945). He found that yields of Dallisgrass (*Paspalum dilatatum* Poir) and sugarcane responded to applications of several phosphorus sources. Dallisgrass yields over a 5-year period increased from 13 Mg ha^{-1} to 17.4 Mg ha^{-1} and phosphorus content increased from 0.08 to 0.11%. If phosphate was omitted after the first year, yield and tissue phosphorus dropped to nearly one-half of that where phosphate was added each year. On the other hand, he found that sugarcane yields were reduced about 15% where superphosphate was applied and the stalks contained 0.094% P compared to 0.066% P for the control. Neller (1942) reported that the yield of sugarcane without phosphorus fertilizer was 71 Mg ha^{-1} compared to 58 Mg ha^{-1} where superphosphate was applied at the rate of 62 kg P ha^{-1}. There was a corresponding drop in sugar content of the crop.

Neller (1944) reported the mineral composition of 10 grasses and 10 legumes grown on soils in the Everglades. The legumes were higher in calcium, magnesium, and phosphorus than the grasses. Andreis (1959) observed that St. Augustinegrass (Stenotaphrum secundatum (Walt.) Kuntze) and Pangolagrass (Digitaria decumbens Stent.) grown on a virgin Histosol fertilized with 15.5 kg P ha^{-1} yielded 31.4 and 53.4% more dry matter than on the control. Allen and Kidder (1952) had stated that normal growth of pasture on virgin muck soils was achieved without phosphorus fertilization, but that with time, the need for phosphate fertilizer on pasture increased.

Forsee and Hoffman (1950) found that the phosphorus requirement of snap beans (Phaseolus vulgaris L.) was met if 17 or more kg P ha^{-1} were present in the soil by water extraction. He recommended that for each kg below 8 kg P ha^{-1} by the soil test, 7 kg P ha^{-1} should be added as fertilizer. With field corn (Zea mays L.), Forsee et al. (1954) determined that yield responses to superphosphate applications occurred where fewer than 10 kg P ha^{-1} were extracted with distilled water.

Soil Testing for Phosphorus Availability

The phosphorus status of Histosols was investigated by Forsee (1942). He noted that where 2.2 kg P ha^{-1} were extracted by 0.5N CH_3COOH, severe phosphorus deficiency of corn leaves resulted and was absent if the soil test was 7 kg P ha^{-1} or more. He also reported that where concentrated superphosphate was added at rates from 11 to 110 kg P ha^{-1}, the kg P ha^{-1} by the soil test increased from 9.5 to 31.9, or about 22% recovery. With celery (Apium graveolens L.), Forsee (1945) found that extraction of both soils and stalks with 0.5N CH_3COOH gave no correlation between soil and tissue phosphorus values. However, levels of phosphorus in soil, as determined by carbonic acid and water extractions, very closely approximated the results of tissue tests by the 0.5N CH_3COOH method. In another study, Forsee (1950) determined that addition of 0, 550, or 1,100 kg S ha^{-1} increased celery yields from 329 to 390 crates ha^{-1}, whereas 0, 77, and 154 kg P ha^{-1} increased the yields from 356 to 404 crates ha^{-1}. He attributed the effect of sulfur to the lowering of the pH to 5.4 and corresponding water-soluble phosphorus increase from 19 to 29 kg ha^{-1}. He found that with the increase in phosphorus applied, water-extractable values increased from 16 to 34 kg P ha^{-1}.

Forsee (1953) found that yield of celery increased differently on two Histosols where soil tests for phosphorus increased from 14 to 25 kg P ha^{-1}. At that time, he recommended that at least 9 kg P ha^{-1} by water extraction be present in the soil and stated that it took 9.6 kg P ha^{-1} from fertilizer to raise the level of phosphorus by soil test by 1.1 kg P ha^{-1}. Further investigations on phosphorus availability in Histosols were carried out by Hortenstine and Forsee (1960). They concluded that these soils should be below pH 6 and that, for 9 crops, the available phosphorus by water extraction should range between 7 and 11 kg P ha^{-1}, except for celery which requires 33 kg P ha^{-1} by the soil test.

Gascho and Kidder (1979) noted that, within a few months after phosphorus application to Pahokee muck, soil test values decreased to a range of 2 to 11 kg P ha^{-1} during the next 35 months. They noticed a more pronounced difference in the amount of available phosphorus at four rates of phosphorus application in Okeelanta sandy muck compared to Pahokee muck. They found a direct relationship between kg P applied ha^{-1} for three years for sugarcane and stalk count in 600 cm of row. Maximum yield of sugar ha^{-1} was found at a total applied amount of 112 kg P ha^{-1} and at a stand count of 78 stalks in 600 cm of row. They recommended that the soil test be no more than 8 kg P ha^{-1}, since excessive soluble phosphorus has a detrimental effect on the sugar content of sugarcane juice.

Leaching of Phosphorus in Histosols

Forsee and Neller (1942) applied fertilizer phosphorus to Everglades soil in lysimeters and monitored the phosphorus recovered in crops and leachates over a period of 35 months. During this time, total rainfall was 454 cm. Phosphorus additions amounted to 0, 141, and 245 kg P ha^{-1} over the study period. The authors noted that the soil water in the sub-irrigation system contained a measurable quantity of phosphorus and accordingly corrected treatment values for added phosphorus leached by substracting the control value. This placed estimates for added phosphorus leached during the study period at about 1.7 to 3.9 kg P ha^{-1}, which was very low in comparison to the 59 to 84% of added phosphorus removed by crops over the same period.

Lucas (1982) illustrated the effect of pH on leachable phosphorus for an Okeechobee muck low in iron and aluminum. The leachates contained higher amounts of phosphorus at soil pH 4.9 than pH 5.5 or 6.2. However, at pH 7.0 to 7.5, phosphorus in the leachate was several times lower than in the acid soils. He reported a similar test in Pahokee muck, which contained about 10 times more iron and aluminum. In the latter soil, there were 2.8 mg P L^{-1} in the leachate at pH 6.2, compared to 16 mg P L^{-1} for the previous study. In another study with Pahokee muck, Lucas (1982) investigated the changes in water-soluble phosphorus at 30 and 210 days after application of triple superphosphate at 0, 165, and 330 kg P ha^{-1}, at depths 0 to 0.05 m, 0.05 to 0.10 m, and 0.15 to 0.30 m. He observed that the greatest change in water-soluble phosphorus took place at the shallowest depth at 30 days. At 210 days, he found that the increase in water-soluble phosphorus with phosphorus rate was similar in the top two depths, whereas the response to rate of applied phosphorus was negligible at 0.15 to 0.30 m depth at both dates. At another site with soil pH 7.2, which had been flooded for 40 of the 210 days, the pattern of phosphorus distribution at identical rates was similar to that of the soil at pH 6.0.

Larsen et al. (1958) studied leaching of fertilizer phosphorus applied to five Histosols in Indiana. They applied 246 kg P ha^{-1} and, after 3 days, leached with 30 cm of water. They concluded that where 9,700 kg ha^{-1} of sesquioxides were present, less than 2% of the phosphorus was recovered in the leachate, whereas the soil with 2,600 kg ha^{-1} of sesquioxides lost 14% of the applied phosphorus. A virgin soil with a slightly lower level of sesquioxides lost 61%. They noted that a muck soil which had been drained, cultivated for 6 years, and heavily fertilized, had a much lower amount of phosphorus in the leachate than virgin muck, even though the water-soluble phosphorus value was 34 kg P ha^{-1} for the fertilized muck compared to 4.5 kg P ha^{-1} for the virgin.

Histosols in the tidewater area of North Carolina were found to be quite acid and leached applied phosphorus readily, in studies by Fox and Kamprath (1971). They concluded that these organic soils had only trace amounts of inorganic minerals and no reservoir of iron and aluminum to be released, because it was tightly bound by the organic matter. When aluminum chloride was added, they found that all of the added phosphorus was retained. Hortenstine and Forbes (1972) determined that inorganic phosphorus in soil solution samples was much higher in a newly cleared, drained Histosol than in an uncleared swampy Histosol and that organic phosphorus levels showed the opposite trend.

Quality of Drainage Water from the Everglades

Lutz (1977) described the water conveyance system from Lake Okeechobee and the Everglades Agricultural Area to the Conservation Area. There are four pump stations which influence the water quality and ecology of the Areas. Pump station S-5A is the largest and serves a 52,795 ha agricultural basin by removing excess water and discharging it into Conservation Area 1. Pump station S-6 is located in the Hillsboro Canal and drains 35,445 ha. The S-6 station also discharges into Conservation Area 1. Pump station S-7 is used to drain 33,372 ha of the Everglades Agricultural Area associated with the North New River Canal and discharges into Conservation Area 2A. Pump station S-8 is on the Miami Canal and serves 51,587 ha of the Everglades Agricultural Area. The S-8 station discharges into C-123 at the northwestern corner of Conservation Area 3.

Lutz (1977) reported the analysis of water samples collected from the four stations during a 20-month long period. In this review, orthophosphate and total phosphate levels in the water are discussed. There was a significantly higher level of both forms of phosphorus at the S-5A station. The total mass loadings of phosphorus were 74, 29, 17, and 58 Mg for the S-5A, S-6, S-7, and S-8 stations, respectively. At all pump stations there was a wide range in orthophosphate and total phosphorus between samplings. In Table 1 of his report, the average total phosphate concentrations for stations S-5A, S-6, S-7, and S-8 were 0.084, 0.055, 0.042, and 0.053 mg L^{-1}, respectively. The corresponding percentages of orthophosphate in the total phosphate were 67, 62, 62, and 60.

Volk and Sartain (1976) examined the phosphorus concentrations of drainage water from 25 locations in the Everglades Agricultural Area. They found no significant difference between locations, but the coefficient of variation was 128%. Differences in phosphorus concentrations were significant, however, between dates of sampling with a range from 0.02 to 0.23 mg P L^{-1}.

Snyder and Shih (1982) reported that at water table depths of 0.30, 0.60, and 0.90 m and corresponding drainage outflows of 1.05, 0.65, and 0.48 m, the annual phosphorus loadings of lysimeter drainage water were 14.9, 3.6, and 0.7 kg ha^{-1}, respectively.

Organic Phosphorus in Soil

The early history of work on organic forms of phosphorus in soil was reviewed by Black and Goring (1953). They discussed the methodology of separating inorganic and organic fractions of soil phosphorus as well as the forms of organic phosphorus, phospholipids, nucleic acids, phytin, and phosphorus acid esters of inositol which were recognized at that time. These authors also reported that the soil organic phosphorus exists in an inherently unreactive state because soils usually have a low level of enzyme activity. They also noted that there may be considerable inorganic phosphorus in microbial cells, but the evidence was that organic phosphorus forms are essentially insoluble. They concluded, from the work of many investigators, that there was some mineralization of organic phosphorus with subsequent utilization by plant roots.

Cosgrove (1967) elaborated on the fact that many microorganisms have an enzyme system capable of hydrolyzing sodium phytate. He noted that sodium phytate is soluble in water, whereas phytin is not. He also placed some emphasis of the fact that organic phosphates in plant and animal residues probably decompose rapidly so that microbial formation of phytin may be the end result.

Further evidence of microbial transformations in the phosphorus cycle was presented by Cosgrove (1977). He pointed out that the largest form of phosphate ester in the soil is the inositol polyphosphate mixture. He reported that phosphatases and phytases may be present in ectomycorrhizas which could contribute to the labile soil phosphate pool. However, he stated that inositol polyphosphates are resistant to enzymatic breakdown because of their ability to form very stable iron and aluminum compounds. He pointed out that colloidal fulvic acid, ferric phosphate complexes, and microbial matter need to be removed by ultra-centrifugation or filtration through a 0.01 μ membrane filter in order to assay for the inorganic phosphate fraction in natural water.

Mayaudon and Simonart (1964) determined that, within 10 minutes, soluble orthophosphate was taken up by soil organisms and was transformed to a component of ribonucleic acid (RNA) and, after 2 days, the soluble phosphorus appeared in the deoxyribonucleic acid (DNA) fractions.

The role of hyaline and melanic fungi in phosphorus mineralization and plant availability of phosphorus was investigated by Kapoor and Haider (1982). They incorporated ^{32}P as orthophosphate and ^{14}C as glucose in hyaline fungi and melanic fungi, and grew wheat (Triticum aestivum L.) seedlings in two soils which were low in organic carbon and contained 30 to 37 mg P kg^{-1} soil by 0.5$\underline{M}$ $NaHCO_3$ extractions. Mycelia containing 2 mg P pot^{-1} (40 kg P ha^{-1}) were mixed with the soil and planted to wheat seedlings. After growing for 2 and 5 weeks, the plants were harvested, and the radioactivity and phosphorus content were determined. The dry matter production and phosphorus uptake by the plants was higher with hyaline fungi biomass and decreased with increasing melanization of the applied fungal cells. They determined inorganic and organic phosphorus in the sodium bicarbonate extracts of the fungal material, and concluded that from 50 to 70% of the extractable phosphorus was in the organic form.

Waksman (1952) discussed the method of estimating available phosphorus by a number of biological methods. These included phosphate uptake by rye seedlings and the amount of growth made by phosphate-requiring bacteria, such as Azotobacter, or fungi, such as Aspergillus, where soil provided the only phosphorus supply.

Methods of Inorganic and Organic Phosphorus Separation

General Experience with Separations

As Black and Goring (1953) reported in their review of organic phosphorus in soils, work on this identification began about 120 years ago. They summarized the findings to the year 1953 and stated that only one general procedure was in use for the determination of organic phosphorus. This procedure was the determination of inorganic phosphorus in extracts before and after some treatment to change the organic phosphorus to an inorganic form. The amount of organic phosphorus was obtained by difference. This could be done to the soil itself or to a soil extract containing organic phosphorus. They mentioned that there were two techniques for determining total soil phosphorus, either dry combustion or wet combustion, both of which have been the subject of considerable research to improve organic phosphorus recovery. They stated that the main problem with dry combustion was volatile loss of phosphorus during ashing and, with wet combustion, the incomplete hydrolysis of organic phosphorus forms during acid treatments.

Anderson (1975) commented that although a number of comparisons had been made between methods, no single one could be considered superior and that the success of a particular method appeared to be dependent on soil type and environment.

Extraction of Inorganic Phosphorus in Soil

The procedure of Mehta et al. (1954) involved removal of the inorganic phosphorus by heating 1 g of soil with 10 ml of concentrated hydrochloric acid for 10 minutes at about 70^oC and then dilution of the solution. Saunders and Williams (1955) digested 0.5 g of soil with 25 ml 0.1$\underline{N}$ HCl on a water bath at 90^oC for an hour and, after filtration, the residue was leached with further portions of hot 0.1$\underline{N}$ HCl to give a final volume of 100 ml. They studied recoveries by cold 0.1$\underline{N}$ HCl, hot 0.1$\underline{N}$ HCl, cold 4$\underline{N}$ HCl, and 1% 8-hydroxyquinoline in 2.5%, by volume, CH_3COOH, and selected the hot 0.1$\underline{N}$ HCl treatment because it extracted the most inorganic phosphorus with the least hydrolysis of organic phosphorus. Black and Goring (1953) reported other methods of removing inorganic phosphorus. Kaila and Virtanen (1955) used 4N H_2SO_4 at a 1 to 25 ratio of soil to acid at room temperature for 18 hours to remove inorganic phosphorus.

Extraction of Organic Phosphorus in Soil

Following the removal of inorganic phosphorus, several schemes of extracting organic phosphorus have been reported. Mehta et al. (1954) recommended that further treatment be the addition of 30 ml of 0.5N NaOH to the soil samples, recovery of the supernatant liquid by centrifugation, and transfer to the volumetric flask containing the acid extract for inorganic phosphorus. Then the procedure called tor the addition of 60 ml of 0.5N NaOH to the soil sample, covering, and heating at 90°C for 8 hours. They then centrifuged the suspension, poured the supernatant into the flask containing the previous extracts, and brought the solution to volume with water. They digested a 15-ml aliquot with 1 ml of 72% perchloric acid to destroy the organic matter and then determined the phosphorus by a colorimetric method. They took an aliquot of the soil extract after the suspended material had flocculated and determined phosphorus concentrations directly on this solution.

Saunders and Williams (1955) found that one extraction with 0.1N NaOH for 16 hours at 90°C gave the same recovery as one cold treatment with 0.1N NaOH for 16 hours.

Hedley et al. (1982) modified the previous method of organic phosphorus extraction to include a sonic vibration step and filtration.

with a further extraction with 30 ml of 1N HCl for 16 hours, followed by digestion with 5 ml of concentrated sulfuric acid and 30% H_2O_2, and filtration.

Total Phosphorus by Ignition

Mineralization of organic phosphorus by ignition methods was discussed by Anderson (1975). He and several other workers (Saunders and Williams, 1955; Dormaar and Webster, 1964; and Kaila and Virtanen, 1955) noted that there were two possible inherent errors in the use of dry combustion. One is the incomplete breakdown of organic phosphorus to inorganic phosphorus, and the other is the increase in solubility of inorganic phosphorus during the ignition process. In general, they found that such errors could be minimized by ignition at 550°C followed by extraction with sulfuric acid of sufficient strength to remove the total organic phosphorus released in the process. A comparison of organic phosphorus in 40 peat samples in the study of Kaila and Virtanen (1955) showed that results were usually in good agreement between the ignition and sodium hydroxide extraction methods. Anderson (1955) summarized the methods of measuring total soil organic phosphate (Table 1).

Hydrolysis of Phosphate Esters during Extraction

The fact that mineralization of organic phosphorus is recognized makes it not too surprising that hydrolysis of phosphate esters might occur during the acid and alkaline extractions of soil. Evidence is given in Table 2 which is a modification of tables given by Anderson (1960), and Dormaar and Webster (1963). This means that stability

Table 1. An outline of some extraction methods for measuring total organic P in soil.†

Separation method	Acid pretreatment		Alkaline treatment	
	Extractant	Time and temperature	Extractant	Time and temperature
Dean (1938)	CH_3COONa	Leach	0.25N NaOH	16 hr at 90°C
Pearson (1940)	0.1N HCl	5 minutes and leach	0.5N NH_4OH	18 hr at 90°C
Ghani (1943)	0.5N CH_3COOH	2 hr	0.25N NaOH	2 hr, repeated
Williams (1950)	0.5% CH_3COOH plus 1% 8-hydroxyquinoline	16 hr	0.1N NaOH	16 hr, at 20°C
Mehta et al. (1954)	12N HCl	10 min., 70°C; let stand for 1 hr	0.5N NaOH 0.5N NaOH	1 hr 8 hr at 90°C
Saunders and Williams (1955)	0.1N HCl	1 hr at about 90°C	0.1N NaOH	16 hr, repeated once
Kaila and Virtanen (1955)	4N H_2SO_4	18 hr	0.5N NaOH 0.5N NaOH	18 hr 4 hr at 90°C

† Adapted from Anderson (1975).

Table 2. Hydrolysis of phosphate esters added to soil during separation of inorganic and organic fractions by several methods.

	Phosphate esters added					
Separation method	Glucose-1-phosphate	β-glycerophosphate	Lecithin	Phytin or inositol phosphate	RNA	DNA
	Hydrolysis, %					
	Soils studied by Anderson (1960)					
Mehta et al. (1954)	100	15	-	15	40	45
Saunders and Williams (1955)	100	10	-	10	15	20
	Soils studied by Dormaar and Webster (1963)					
Mehta et al. (1954) modified by Anderson (1960)	40	-	5	10	8	4
Kaila and Virtanen (1955)	58	-	30	23	32	25

appears to be greatest for phytin or inositol hexametaphosphate, and that ribonucleic acid (RNA), deoxyribonucleic acid (DNA), and glucose-1-phosphate are more subject to hydrolysis. Anderson (1960) found incomplete recovery of the above phosphate forms during either ignition (Table 3) or acid extraction of unignited soil with 2N H_2SO_4 (Table 4).

Table 3. Recovery of P from phosphate esters added to soil and then ignited.†

Glucose-1-phosphate	β-glycero-phosphate	Inositol hexa-phosphate	RNA	DNA
Recovery, %				
5	80	80	80	100

† Adapted from Anderson (1960).

Table 4. Hydrolysis of added phosphate esters during acid extraction of unignited soils.†

Glucose-1-phosphate	β-glycero-phosphate	Inositol hexa-phosphate	RNA	DNA
Hydrolysis, %				
100	25	5	15	10

† Adapted from Anderson (1960).

MATERIALS AND METHODS

Soil Classification and Characteristics

The organic soil studied was Pahokee muck (a euic, hyperthermic Lithic Medisaprist), a drained Histosol located at the Agricultural Research and Education Center (AREC), Belle Glade, Florida.

Pahokee muck is a nearly level, very poorly-drained organic soil that rests on limestone located at a depths of 0.90 to 1.27 m (McCollum et al., 1978). It formed in moderately thick deposits of hydrophytic plant remains in broad, freshwater marshes. Under natural conditions, the soil is covered by water, or has the water table within 0.25 m of the surface for 6 to 12 months during most years, except during extended dry periods. In its native state, Pahokee muck is not suited to cultivation. Drainage and water control by means of a system of dikes, ditches, and pumps makes Pahokee muck well-suited to a wide variety of vegetables, sugarcane, and pastures.

Soil reaction ranges from acid to mildly alkaline when measured with a field test kit (McCollum et al., 1978). The pH, when measured in 0.01$\underline{M}$ $CaCl_2$, is more than 4.5 and mineral content ranges from 10 to 45%. McCollum et al. (1978) presented a detailed profile description of Pahokee muck (Table 5).

Table 5. Profile description of Pahokee muck.[†]

Location: Palm Beach County, Florida, 0.5 mile west of State Road 827-A and about 200 feet north of State Road 827, NW1/4SE1/4 sec. 30, T. 44 S, R. 37 E.

Natural vegetation: Sawgrass, willow, bay, elderberry, scattered cypress, and an undergrowth of ferns, pickerelweed, maidencane, and other water-tolerant plants.

Crops: Sugarcane, vegetables, pasture, and sod.

Drainage and permeability: Poorly-drained; rapid permeability.

Available water capacity: Very high.

Natural fertility: Moderate.

Horizon	Depth, m	Description
Oap	0 to 0.25	Black (N 2/0) muck (sapric material): less than 5% fiber unrubbed; moderate coarse subangular blocky structure, parting to moderately fine and medium granular structure; very friable; sodium pyrophosphate extract is dark brown (10YR 4/3); estimated mineral content 35%; slightly acid; clear smooth boundary.
Oa2	0.25 to 0.71	Black (5YR 2/1) muck (sapric material); about 65% fiber, 10% rubbed; massive; sodium pyrophosphate extract is pale brown (10YR 6/3); estimated mineral content about 33%; slightly acid; gradual smooth boundary.
Oa3	0.71 to 1.07	Dark reddish brown (5YR 2/2) muck (sapric material); about 40% fiber, 10% rubbed; massive; sodium pyrophosphate extract is brown (10YR 5/3); estimated mineral content 35%; slightly acid; abrupt wavy boundary.
R	1.07	Hard limestone containing solution holes.

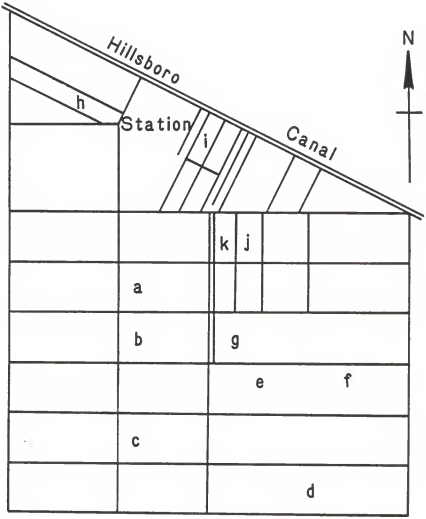
† McCollum et al. (1978).

Sampling and Preparation of Soil

The soil was sampled on September 9 and 10, 1980. Two soil cores were taken from each of 10 cultivated fields and an uncultivated area at the Agricultural and Research Center, Belle Glade. The cultivated fields were three pastures of St. Augustinegrass on which cattle were grazing, two sugarcane fields, a drained rice (*Oryza sativa* L.) paddy, two vegetable fields which had just been disked, a horticultural field which had just been disked, and a fallow field which had been uncropped for the preceding 5 years, but had been disked regularly to control weeds. The uncultivated or virgin area was dominated by elderberry (*Sambucus simpsonii* Rehder). Field locations are shown in Fig. 1.

Soil cores were taken by clearing away surface vegetation where necessary and driving a 9.5 x 43 cm plexiglass cylinder into the soil until the top of the cylinder was flush with the soil surface. Surrounding soil was excavated by shovel and the core was carefully removed. Both ends of the soil column were covered with plastic bags which were held in place with elastic bands. The soil cores were transported to Gainesville, Florida and stored at room temperature ($22^{o}C$) until they were sectioned.

The soil in the cores was removed by carefully digging out selected depth increments from the ends of the cylinder. The soil cores were divided into seven depth increments, 0 to 0.05 m, 0.05 to 0.10 m, 0.10 to 0.15 m, 0.15 to 0.22 m, 0.22 to 0.29 m, 0.29 to 0.36 m, and 0.36 to 0.43 m. Each depth increment was collected in a tared plastic bag and then weighed. The field-moist bulk density of each depth sample was determined from the volume and weight of the sample. The volume was calculated from the cross-sectional area of the cylinder



Symbol	Field	AREC Field
a	Pasture 1	P2E
b	Pasture 2	P3E
c	Pasture 3	P5E
d	Virgin	F6E
e	Cane 1	F4E
f	Cane 2	F4E
g	Rice	F3E
h	Fallow	Near lysimeters
i	Horticulture	F2SE
j	Vegetable 1	F1E2
k	Vegetable 2	F1E1

Fig. 1. Field locations at the AREC, Belle Glade, Florida.

times the depth of the sample. Before further analysis, each depth samples was passed through a 4-mm plastic sieve and thoroughly mixed to ensure homogeneity.

The gravimetric moisture content of the muck samples was determined at $90^{o}C$ after 24 hours. The oven-dry bulk density of each depth sample was calculated from the field-moist bulk density and the gravimetric moisture content. The volumetric moisture content was determined from the oven-dry bulk density and the gravimetric moisture content. The soil samples were stored at $4^{o}C$ prior to further analysis.

Chemical Analysis

Soil Reaction

The pH of a saturated paste of each sample of field-moist muck with water was measured with a glass electrode and a Radiometer PHM research pH meter.

Extraction of Soil Samples with Water

The effects of solution to soil ratio and time of shaking on the extent of inorganic P extracted by water were investigated using soil from a vegetable field and the virgin field (Tables A-1, A-2, and A-3). On the basis of these preliminary trials, the following procedure was adopted. Field-moist muck, equivalent to 1.5 g of oven-dry soil, was weighed into a small blender cup. About 40 ml of deionized water were added and the suspension was blended for 2 minutes. The sample was transferred quantitatively to a tared 250-ml polyethylene bottle and deionized water was added until the volume of water was 150 ml. This gave a water to soil ratio of 100:1. The suspension was shaken at low speed on a reciprocating shaker for 1 hour at room temperature (23 to 25^{o}C). After shaking, the samples were allowed to stand for 30 minutes and then were filtered through a 0.2 μ membrane under suction. A 40 ml-aliquot of the colored water extract was shaken with 250 mg of Darco No. 60 activated carbon in a glass jar for 15 seconds and then filtered through Whatman No. 42 filter paper. This was necessary because it was noticed that there was some factor in the colored water extracts which interfered with the color development for the phosphorus determination (Fig. 2a). This interference was removed by clearing each water extract with activated carbon. Comparison of standard phosphorus solutions that had and had not been shaken with activated carbon indicated that there was negligible adsorption or desorption of phosphorus by the carbon during the clearing process (Fig. 2b).

The concentration of inorganic P (orthophosphate-P) in the clear extracts was immediately determined by the ascorbic acid-ammonium molybdate colorimetric method of John (1970). The spectrometer used was a Bausch and Lomb Spectronic 21 with a 2.3-cm cell path length. A standard curve was constructed from solutions of 0, 0.1, 0.2, 0.3, 0.4, and 0.5 mg P L^{-1} as KH_2PO_4. Absorbance was read at a wavelength of 882 nm. The concentrations of Ca, Mg, and Fe in another portion of each colored water extract were determined by atomic absorption spectrophotometry and K by flame spectrophotometry. The pH of each water extract was measured. The concentrations of all elements were calculated as mg kg^{-1} of oven-dry soil, since the gravimetric water content of the field-moist muck samples was known. Multiplication of these values by the oven-dry bulk density gave concentrations expressed as g m^{-3} on an oven-dry basis, as suggested by Lucas (1982).

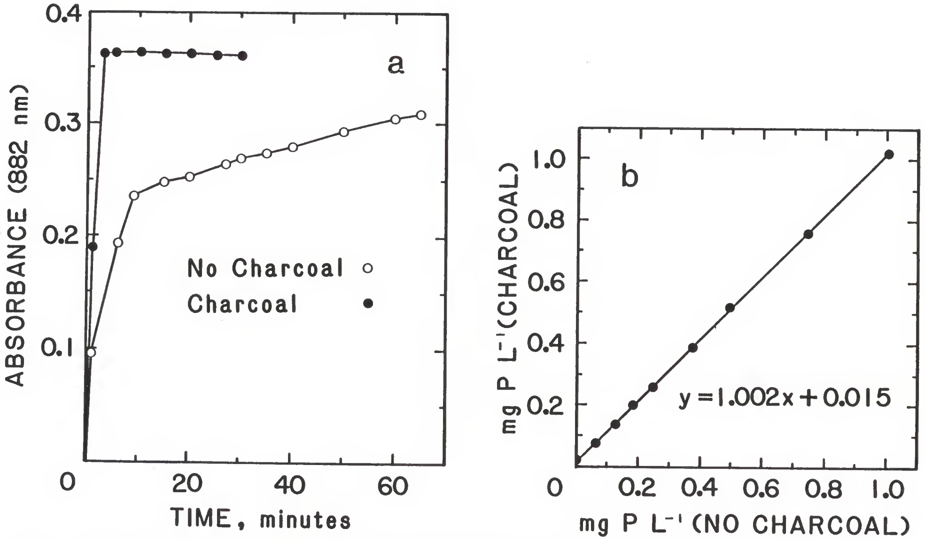


Fig. 2. Effect of charcoal (activated carbon) on (a) absorbance with time and (b) P recovery.

Extraction of Soil Samples with Double Acid Soil Test Reagent

Double acid (DA) is 0.05$\underline{N}$ HCl in 0.025$\underline{N}$ H_2SO_4 as formulated by Mehlich in 1953 (Sartain, 1977). The pH of blank DA reagent is 1.39 and was compared with the pH of extracts from various DA to soil ratios from 10 to 300 (Table A-4). On the basis of the pH of the DA extract and the inorganic P extracted, a solution to soil ratio of 100:1 was selected. The following procedure was adopted. Field-moist muck, equivalent to 0.5 g of oven-dry soil, was weighed into a 125-ml Erlenmeyer flask and 50 ml of DA reagent were added. The suspensions were shaken at a low speed on a reciprocating shaker for 25 minutes at room temperature (23 to 25°C). The extracts were filtered through Whatman No. 42 paper. The concentration of inorganic P in the DA extracts was determined by the colorimetric method of John (1970). Concentrations of Ca, Al, Fe, and Cu in the extracts were determined by atomic absorption spectrophotometry.

Extraction of Soil Samples with Hot 0.1N HCl

The acid pretreatment method of Saunders and Williams (1955) was used. This method had been used previously to separate inorganic and organic P in A and B_2h horizons of Florida Spodosols (Nicholson et al., 1980). Field-moist muck, equivalent to 0.75 g of oven-dry soil, was weighed into an 80-ml test tube and 40 ml of 0.1$\underline{N}$ HCl were added. The suspensions were mixed on a vortex stirrer and the test tubes were placed in a boiling water bath, covered, and heated for 3 hours. After removal from the water bath, the test tubes were cooled for about 5 minutes and stoppered. The contents were mixed by inverting the test tube several times and were filtered through Whatman No. 42 paper while still hot. The test tube and residue on the filter paper were rinsed with an additional 35 ml of hot 0.1N HCl. The final solution to soil ratio was 100:1.

The concentration of inorganic P in the extracts was determined by the colorimetric method of John (1970). Since a large number of the extracts were quite darkly colored, the concentration of total P in the hot 0.1N HCl extracts was determined. An aliquot of the extract was pipetted into a 40-ml glass vial and placed on a hot plate. The volume of the extract was reduced to less than 1 ml by heating slowly, but the samples were not allowed to go to dryness. After these volume reductions, the vials were allowed to cool and 3 ml of concentrated nitric acid were added. The volume of the digest was again reduced to near dryness. While these digests were still hot, 0.5 ml of 30% H_2O_2 was added. After the reaction had ceased, an additional 0.5 ml of 30% H_2O_2 was added. The digests were then evaporated to dryness at low heat to ensure that the peroxide had been completely driven off. Then 2 ml of deionized water were added to the cooled vials. The contents were again evaporated to dryness at a low heat. After cooling, 5 ml of 1N HCl were added to the vials which were heated slowly for 30 minutes. The contents of the vials were transferred quantitatively to a 50-ml volumetric flask with deionized water and the concentration of total P (as orthophosphate-P) in the digested extract was determined by the colorimetric method of John (1970). The difference between the total P and the inorganic P determined in the hot 0.1N HCl extracts was termed organic P extracted by hot 0.1N HCl. Concentrations of Ca, Al, Fe, and Cu in the original extract were determined by atomic absorption spectrophotometry.

Ashing of Soil

Several methods for the determination of total P in the soil samples were compared. These methods were (i) the nitric acid-perchloric acid digestion procedure of Sommers and Nelson (1972); (ii) ignition at 400°C for 2 hours (Dormaar and Webster, 1964); and (iii) ignition at 400°C for 2 hours followed by heating at 600°C for 2 hours. Samples of oven-dry, ground muck from four fields were used. The weight of pulverized soil used was 0.25 g.

Since samples ignited at 400°C for 2 hours were not completely ashed and gave slightly lower values of total P than the other two methods, this method was rejected. Values of total P after ignition at 400°C for 2 hours followed by ashing at 600°C for 2 hours were quite similar for corresponding samples after the nitric acid-perchloric acid digestion. Since the ignition method was both easier to conduct and faster, it was selected for the total P analysis in all samples.

About 15 g of the oven-dry muck samples were ground to a fine powder in an agate mortar. A 0.25-g portion of ground muck was weighed into a tared, oven-dry crucible. The samples were then oven-dried for 24 hours at 90°C and weighed before ignition at 400°C for 2 hours, followed by ashing at 600°C for 2 hours. After ashing, the samples were returned to the oven at 90°C for 24 hours and weighed again. The ash content was calculated on an oven-dry soil basis. These values were multiplied by the oven-dry bulk density to give the weight of ash per unit volume of soil. To each of the crucibles, 5 ml of $\underline{N}$ HCl were slowly added and they were heated on a hot plate for 30 minutes. The contents of each crucible were transferred quantitatively to a 50-ml volumetric flask by repeated washings with $\underline{N}$ HCl. The extracts were brought to volume with N HCl, vigorously shaken, and allowed to stand overnight. The concentration of total P in the extracts was determined by the colorimetric method of John (1970). The concentrations of Ca, Mg, Al, Fe, and Cu in the extracts were determined by atomic absorption spectrophotometry and K by flame spectrophotometry.

Total organic P was obtained by difference between total P by ashing and inorganic P extracted by hot 0.1N HCl. Residual organic P was obtained by difference between total P by ashing and total P extracted by hot 0.1N HCl.

Aerobic Incubation Experiments

General Description

The effects of P and corn stover, added to Histosol samples, on the production of carbon dioxide and on water-soluble inorganic P were studied using surface (0 to 0.15 m) soil from a vegetable field and the virgin field. Inorganic P as KH_2PO_4, was added at 0, 20, 40, and 80 mg P kg^{-1} of oven-dry soil, with or without corn stover, which was added at 22.4 Mg ha^{-1} (10 tons $acre^{-1}$). The treatments were run in duplicate.

Field-moist soil was passed through a 2-mm sieve and then air-dried to a gravimetric moisture content of 50 to 60%. An amount of soil, equivalent to 15.00 g of oven-dry soil, was weighed into a weighing boat and transferred to a tared 250-ml Erlenmeyer flask containing the weight of liquid required to raise the moisture content of the soil to that at field capacity. The moisture content of each soil at field capacity had been previously determined using Tempe cells at a tension of 0.033 MPa. The flask and its contents were weighed, the soil was mixed well with a stirring rod, and the flask and its contents were again weighed. The actual weights of moist soil in the flasks after mixing were calculated. In the cases where corn stover was added, the equivalent of 0.60 g of oven-dry stover was weighed into a weighing boat and transferred to the flask after the addition of soil.

Experiment 1: Measurement of Carbon Dioxide Production

The flasks containing the samples to be incubated for the measurement of carbon dioxide were attached to a closed aeration system (Fig. 3). This system consisted of two aquarium-type pumps that forced air through an Erlenmeyer flask containing 900 ml of 4*N* NaOH, followed by passage through a flask containing 600 ml of deionized water to saturate the carbon dioxide-free air entering a manifold with 36 outlets. Each outlet was attached to an incubation flask, an empty 80-ml test tube, and an 80-ml test tube containing 25 ml of 0.15*N* NaOH to trap the carbon dioxide produced by the soil during incubation. The rate of air input was adjusted so that a bubble emerged from the end of the glass tube in the carbon dioxide trap just as the previous bubble broke the surface of the dilute sodium hydroxide solution. Four empty flasks served as controls for carbon dioxide output.

The samples were incubated at room temperature (26 to 29^{o}C) for 47 days. The carbon dioxide evolved from the samples without added corn stover was measured after 2, 5, 13, 20, 29, and 47 days, while that from samples with added corn stover was measured after 2, 3, 4, 5, 7, 10, 14, 20, 29, and 47 days. Before determination of the amount of carbon dioxide trapped by the sodium hydroxide in the exit tubes, the pumps were turned off and the test tubes containing the trapped carbon dioxide were removed and immediately stoppered. The glass tubes were

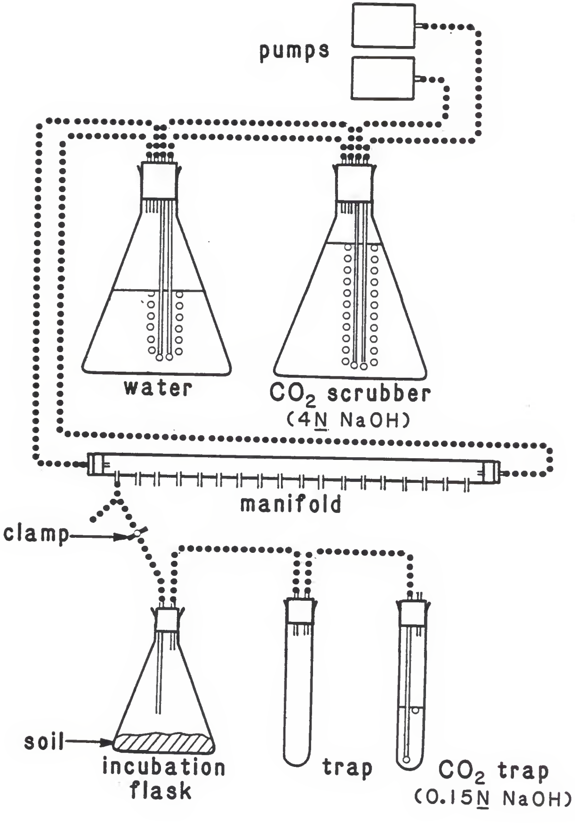


Fig. 3. Schematic diagram of apparatus used for carbon dioxide evolution.

wiped dry and a new set of 80-ml test tubes containing 25 ml of freshly prepared 0.15N NaOH was attached to the system. The amount of carbon dioxide evolved was determined by titrating a 10-ml aliquot of the exit sodium hydroxide solution to a phenophthalein endpoint (pH 8.1) with standardized 0.15N HCl.

The 4N NaOH in the carbon dioxide scrubber was renewed once a week. The scrubber was disconnected from the rest of the system and air was bubbled through it for 30 minutes to remove any carbon dioxide introduced while the solution was being changed.

Experiment 2: Changes in Water-Extractable Inorganic P

Long-term incubation

Another complete set of samples, with the same treatments as above, was set up to investigate the change with time in water-extractable inorganic P. The flasks were covered with Mylar film held in place with an elastic band to minimize moisture loss, while permitting free exchange of oxygen and carbon dioxide. The samples were incubated at room temperature (25 to 28°C) for 48 days. After 5 days of incubation, each of the flasks was weighed and the contents were mixed well with a spatula. An amount of the incubated soil, equivalent to 1.5 g of oven-dry soil, was transferred to a blender cup and extracted with water as described previously. The flask was weighed and was again covered with Mylar film. Sampling was repeated after 9, 15, 37, and 48 days of incubation.

The concentration of inorganic P in the water extracts was determined by the colorimetric method of John (1970), after clearing with activated carbon as described previously. Concentrations of Ca, Mg, and Fe in aliquots of the uncleared extracts were determined by atomic absorption spectrophotometry and K by flame spectrophotometry. Concentrations of nitrate in the uncleared extracts were determined with an Orion Model 93-07 nitrate electrode coupled to an Orion Model 90-02 double-junction reference electrode, and an Orion Model 701 digital pH/mV meter. Standards of 1.4, 3.5, 7.0, 14, 35, 70, and 140 mg NO_3-N L^{-1} were prepared from a 0.1$\underline{N}$ NH_4NO_3 stock solution.

Short-term incubation

In order to investigate the changes in water-extractable inorganic P over a shorter period of incubation, another complete set of samples, with the same treatments as before, was prepared. The samples were incubated at room temperature (23 to 25^{o}C) and were sampled, following the procedure described above, after 1, 3, 5, and 7 days of incubation. In addition, soil from each of the treatments was extracted with water immediately after preparation to give an estimate of the initial values of water-extractable elements.

Leaching Experiment

A weight of soil, equivalent to 6.00 g of oven-dry soil, was shaken with 600 ml of deionized water in a polyethylene bottle for 16 hours at a slow speed on a reciprocating shaker. This was done in duplicate with soil from the 0 to 0.15 m depth from (i) a vegetable field; (ii) a rice paddy; and (iii) the fallow or uncropped field. The suspension was quantitatively transferred to a tared 0.2 µ membrane filter apparatus and filtered with suction applied. Concentrations of inorganic P, nitrate-N, Ca, Mg, K, and Fe in the water extracts and the pH were determined as described above.

The membrane filter apparatus, with only the water-extracted soil, was weighed and the gravimetric water content of the soil was calculated. The lower compartments of the filter assemblies were rinsed several times with deionized water. Lids were placed on the filter assemblies and the soil samples were incubated at room temperature (23 to 25^{0}C) for 15.5 days. The filter assemblies and their contents were weighed and 70 g of deionized water were slowly added to the upper compartments of each assembly. After standing for an hour, the water was pulled through the soil by suction. The water extracts were poured into sample containers and the filter assemblies and their contents were weighed again. After rinsing the lower compartments several times with deionized water, lids were placed on the filter assemblies. The incubation of the soil was continued and further leaching was performed on 32.5, 41.5, and 58.5 days after initiating the experiment.

Incubation of Soil at Various Water Contents Under Atmospheres of Air and Dinitrogen Gas

An amount of moist muck, equivalent to 3.00 g of oven-dry soil, from the 0 to 0.15 m depths of the rice paddy was weighed into each of 36 tared 40-ml glass bottles. There were six treatments of gravimetric water content, namely at 175, 200, 225, 250, 555, and 823%, made by the addition of boiled, deionized water. The samples were mixed well with a glass stirring rod and reweighed.

Soils at each moisture content were put into two groups. In one, the tops of the bottles were covered with Mylar film to minimize the loss of moisture, but allow free exchange of oxygen and carbon dioxide. The remaining three bottles at each moisture content were fitted with rubber septa. The sample atmosphere was purged with dinitrogen gas for

30 minutes. This was followed by evacuation by suction for 10 minutes and by a second purging with dinitrogen gas for 30 minutes. All 36 samples were incubated at room temperature (23 to 25^{o}C) for 23 days.

At the end of the incubation, the depths of water standing above the soil incubated at 250, 555, and 823% gravimetric water content were 2, 8, and 25 mm, respectively. The redox potential of the soil was measured with an Orion Model 96-78 platinum electrode and calomel cell by an Orion Model 701 digital pH/mV meter. The soil samples were mixed well with a glass rod and quantitatively transferred to a tared 0.2 μ membrane filter assembly by repeated washings with deionized water. The final weight of soil and water in each of the assemblies was adjusted to 93 g with deionized water to have the same soil to water content. The suspension was filtered through the membrane filter under suction. The concentrations of inorganic P, nitrate-N, Ca, Mg, K, and Fe in the water extracts and the pH were determined as previously described.

Statistical Analysis

The computer used for the statistical analysis was an Amdahl V-6-II and IBM 3033 with an OS/MVS Release 3.8 and J 252/NJE Release 3. The computer software used was the Statistical Analysis System (SAS User's Guide, 1979).

Analysis of the Determinations on Depth Samples from Fields

Analysis of variance (ANOVA) for each determination was performed using a completely randomized model in a factorial design with equal replication. Fields and depths were considered to be factors. For the water extractions, there were seven field levels, while for all other extractions, there were 11 field levels. Seven depth levels were used throughout. Since two cores had been taken from each field, these were considered as replicates.

The analysis of variance procedure, PROC ANOVA, of the Statistical Analysis System (SAS) was used. The model used was a two-factor main effects model with a crossed factor:

```
PROC ANOVA;
  CLASSES FIELD DEPTH;
  MODEL (variable) = FIELD DEPTH FIELD*DEPTH;
```

If the field x depth (FIELD*DEPTH) interaction was not significant, differences between the means of the main effects (FIELD and DEPTH) were analyzed by Duncan's Multiple Range Test at the 5% level by the inclusion, directly after the MODEL statement, of:

```
  MEANS FIELD DEPTH/DUNCAN;
```

If the field x depth interaction was significant, differences between fields at each depth or between depths within each field were analyzed by running the DUNCAN procedure of SAS in a subsequent job. Mean square error (MS) values, previously calculated by running the ANOVA procedure described above, and corresponding degrees of freedom (DF) were entered as outlined by the SAS User's Guide (1979).

Analysis of Carbon Dioxide Evolved during Aerobic Incubation of Soil Samples

In order to analyze the evolved carbon dioxide data, amounts measured at each sampling period were expressed in terms of daily carbon dioxide production per g of soil. Analysis of variance was performed using a completely randomized model in a factorial design with equal replication. Soil (S), rate of added phosphorus (PR), and time (T) of sampling were considered to be factors. Since the presence of added corn stover had a dramatic effect on the evolution of carbon dioxide from both soils, it was rejected as a factor in the ANOVA model. Instead, the ANOVA procedure was performed independently on soil with and without added corn stover. In both cases, the model used was a three-factor main effects model with crossed factors:

```
PROC ANOVA;
  CLASSES S PR T;
  MODEL CO2RATE=S PR T S*PR S*T PR*T S*PR*T;
```

Significant differences between means were analyzed by Duncan's Multiple Range Test in a manner similar to that described above.

Analysis of Determinations on Soil Incubated Under Air and Dinitrogen Gas

Analysis of variance for each determination on the incubated soil was performed using a completely randomized design with equal replication. Moisture content (H20) and atmosphere (ATM) over the soil samples during the incubation were considered as factors. The model used was a two-factor main effects model with a crossed factor:

```
PROC ANOVA;
  CLASSES H20 ATM;
  MODEL (variable) = H20 ATM H20*ATM;
```

Significant differences between means were analyzed by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Bulk Density

The values of bulk density for the samples of Pahokee muck studied ranged from 0.149 to 0.467 Mg m^{-3} and agreed well with those reported for this soil by Terry (1980). Analysis of variance indicated that there was a very highly significant difference between the means for bulk density (Table A-32). The coefficient of determination, r^2, was 0.90, which means that the model accounted for 90% of the variation in bulk density. There was also a very highly significant field x depth interaction, indicating that bulk density changed with depth in a different manner between fields. Due to this interaction, further analysis centering on differences between means for each depth and field was done (Table A-5). The nature of the interaction is shown in Fig. 4, where the data have been grouped for convenience in presentation. It should be noted that the analysis of variance was performed on all of the field and depth combinations at the same time.

In general, the bulk density initially increased with depth and then decreased after reaching a maximum (Fig. 4). The magnitude and depth of the maximum bulk density varied between fields.

Changes in Bulk Density with Depth by Fields

In Pasture 1, the maximum bulk density of 0.340 Mg m^{-3} occurred in the 0.05 to 0.10 m depth, but this value was not significantly different from that at the 0.10 to 0.15 m depth. Below 0.15 m, the bulk density

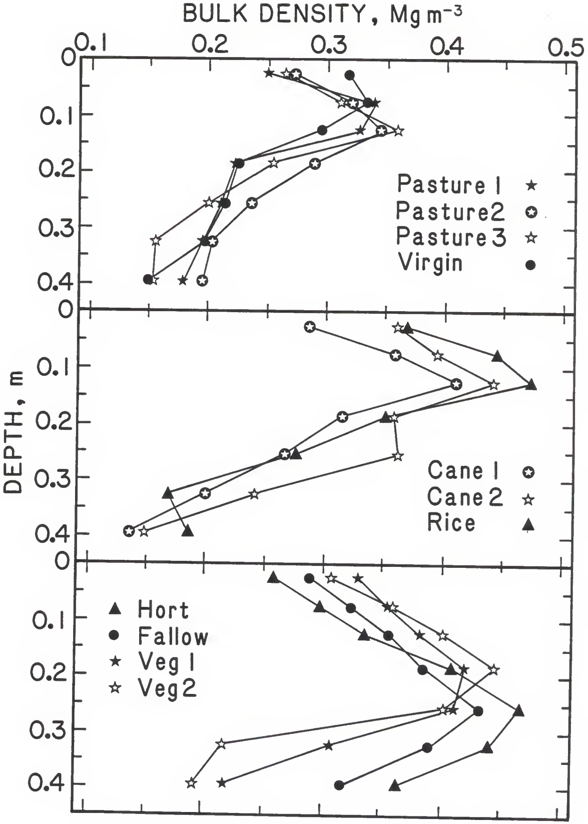


Fig. 4. Oven-dry bulk density of Pahokee muck from 11 fields sampled at seven depths.

was significantly less and decreased to a minimum ot 0.178 Mg m^{-3} in the 0.36 to 0.43 m depth.

In Pasture 2, the maximum bulk density was 0.344 Mg m^{-3} in the 0.10 to 0.15 m depth, but this value was not significantly different from others found from 0 to 0.22 m in this field. Below the 0.10 to 0.15 m depth, the bulk density decreased to a minimum of 0.195 Mg m^{-3} at the 0.36 to 0.43 m depth, but this value was not significantly different from values in the 0.22 to 0.29 and 0.29 to 0.36 m depths.

In Pasture 3, the bulk density increased with depth to a maximum of 0.359 Mg m^{-3} at the 0.10 to 0.15 m depth. However, this value was not significantly different from that for the 0.05 to 0.10 m depth of this field. Below 0.10 to 0.15 m, the bulk density decreased to a minimum of 0.153 Mg m^{-3} at 0.36 to 0.43 m, but this value was not significantly different from values determined for the 0.22 to 0.29 and 0.29 to 0.36 m depths.

In the Virgin area, a maximum bulk density of 0.333 Mg m^{-3} occurred in the 0.05 to 0.10 m depth, but this was not significantly different from values in the 0 to 0.05 and 0.10 to 0.15 m depths. Below 0.10 m, the bulk density decreased to 0.149 Mg m^{-3} for the 0.36 to 0.43 m depth, but this value was not significantly different from values for the 0.15 to 0.36 m depths.

In the first sugarcane field, Cane 1, the bulk density increased with depth to a maximum of 0.410 Mg m^{-3} at the 0.10 to 0.15 m depth, but this was not significantly different from the value for the 0.05 to 0.10 m depth. The minimum bulk density, 0.136 Mg m^{-3}, occurred at 0.36 to 0.43 m in this field, but this value was not significantly different from that at the 0.29 to 0.36 m depth.

In the Cane 2 field, the maximum bulk density of 0.442 Mg m^{-3} was determined for the 0.10 to 0.15 m depth, but this value was not significantly different from those for the 0 to 0.29 m depths. The bulk density in this field decreased to a minimum of 0.149 Mg m^{-3} in the 0.36 to 0.43 m depth and this value was significantly different from all other values of bulk density for this field.

In the Rice paddy, a maximum bulk density of 0.474 Mg m^{-3} occurred in the 0.10 to 0.15 m depths, but this value was not significantly different from that for the 0.05 to 0.10 m depth. The minimum value was 0.168 Mg m^{-3} at 0.29 to 0.36 m, but this was not significantly different from that at the 0.36 to 0.43 m depth, both values being significantly different from all other values for this field.

In the Horticulture field, the 0.22 to 0.29 m depth had the maximum bulk density. This value, 0.467 Mg m^{-3}, was not significantly different from values of bulk density determined at the 0.15 to 0.22 m and 0.29 to 0.36 m depths. In this field, the minimum bulk density was 0.259 Mg m^{-3} at the 0 to 0.05 m depth and was not significantly different from other low values determined for the 0.05 to 0.10 m and the 0.10 to 0.15 m depths. Below the maximum at 0.22 to 0.29 m, the bulk density decreased to 0.365 Mg m^{-3} at 0.36 to 0.43 m, which was not significantly different from the value at the 0.29 to 0.36 m depth.

The bulk density in the Fallow or uncropped field followed the same trend. A minimum value of 0.289 Mg m^{-3} occurred in the surface 0 to 0.05 m. This value was not significantly different from values in the 0.05 to 0.10 m and 0.10 to 0.15 m depths. The maximum bulk density was 0.432 Mg m^{-3} at the 0.22 to 0.29 m depth, but this value was not significantly different from values at the 0.10 to 0.15 m, 0.15 to

0.22 m, and 0.29 to 0.36 m depths. Below this maximum, the bulk density decreased to 0.317 Mg m^{-3} at the 0.36 to 0.43 m depth. This value was not significantly different from the bulk density at the 0.29 to 0.36 m depth.

In the first vegetable field, Vegetable 1, the maximum bulk density of 0.421 Mg m^{-3} occurred at the 0.15 to 0.22 m depth. This value was not significantly different from values determined at depths from 0 to 0.29 m. Below the 0.15 to 0.22 m depth, the bulk density decreased to a minimum value of 0.218 Mg m^{-3} at the 0.36 to 0.43 m depth, which was significantly different from all other values determined for this field.

In the Vegetable 2 field, the bulk density increased to a maximum of 0.445 Mg m^{-3} at the 0.15 to 0.22 m depth, and then decreased to a minimum of 0.192 Mg m^{-3} at the 0.36 to 0.43 m depth. The maximum value was not significantly different from values determined for the depths from 0.05 to 0.29 m, while the minimum value was not significantly different from the value for the 0.29 to 0.36 m depth.

Changes in Bulk Density with Field by Depths

At the 0 to 0.05 m depth, the maximum bulk density of 0.368 Mg m^{-3} occurred in the Rice paddy and was significantly different from values determined for this depth in the Pasture 1, Pasture 3, and Horticulture fields. The minimum bulk density for the 0 to 0.05 m depth was 0.249 Mg m^{-3} in Pasture 1. This value was significantly different from bulk densities in the Cane 2 and Rice fields.

At the 0.05 to 0.10 m depth, the maximum value of 0.444 Mg m^{-3} also occurred in the Rice paddy soil. This value was not significantly different from values determined for this depth in the Cane 1, Cane 2, Vegetable 1, and Vegetable 2 fields. The minimum bulk density at the 0.05 to 0.10 m depth was 0.289 Mg m^{-3}, determined for the Horticulture field. This value was significantly different from that in the Rice paddy at this depth.

At the 0.10 to 0.15 m depth, the maximum value of bulk density was 0.474 Mg m^{-3} and again occurred in the Rice paddy soil. This value was significantly different from values in the Pasture 1, Pasture 2, Pasture 3, Fallow, and Horticulture fields. The minimum value of 0.294 Mg m^{-3}, at this depth in the Virgin field, was significantly different from values determined in the Cane 1, Cane 2, Rice, and Vegetable 2 fields.

At the 0.15 to 0.22 m depth, the maximum bulk density was 0.445 Mg m^{-3} and it occurred in the Vegetable 2 field. This value was significantly different from values of bulk density determined for the Pasture 1, Pasture 2, Pasture 3, Virgin, and Cane 1 fields. The minimum value of bulk density at this depth was 0.219 Mg m^{-3} in the Pasture 1 field. This value was not significantly different from values for the Pasture 2, Pasture 3, and Virgin fields at this depth.

At the 0.22 to 0.29 m depth, the maximum bulk density was 0.467 Mg m^{-3}, which occurred in the Horticulture field. This value was not significantly different from values of bulk density determined for the Fallow, Vegetable 1, and Vegetable 2 fields at this depth. A value of 0.200 Mg m^{-3}, which occurred in the Pasture 3 field, was the minimum bulk density found at this depth and it was significantly different from values in the Cane 2, Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields.

At the 0.29 to 0.36 m depth, the maximum bulk density was 0.441 Mg m^{-3} and again it occurred in the Horticulture field. This value was not significantly different from that of the Fallow field at this depth. The minimum bulk density at the 0.29 to 0.36 m depth had a value of 0.155 Mg m^{-3} and occurred in Pasture 3. It was significantly different from values in the Horticulture, Fallow, and Vegetable 1 fields.

At the 0.36 to 0.43 m depth, the maximum bulk density was 0.364 Mg m^{-3}, also in the Horticulture field. This value was not significantly different from the bulk density in the Fallow field. The minimum bulk density at the 0.36 to 0.43 m depth was 0.136 Mg m^{-3} in the Cane 1 field and it was significantly different from values in the Horticulture and Fallow fields at this depth.

Main Trends in the Change of Bulk Density with Depth

It was evident from the shape of the bulk density versus depth distributions (Fig.4) that there were three main trends in the data. The first trend was found in the Pasture 1, Pasture 2, Pasture 3, and Virgin fields, which had little or no cultivation. In this group, subsidence would be expected to be the major agent increasing bulk density, especially in depths near the surface. This was apparent in the Virgin soil, where the bulk density was maximal in the 0.05 to 0.10 m depth. In the pastures, the fibrous network of St. Augustinegrass roots and rhizomes may have served to decrease the bulk density of the soil in the surface depths. Trampling of the soil surface by grazing cattle may have compacted the soil and accounted for the sharp increase in bulk density within the surface 0.15 m of the pastures. Statistically, there was no depth at which the bulk densities of the four profiles in this group were significantly different from each other (Table A-5).

The second trend in the distribution of bulk density was found in the Cane 1, Cane 2, and Rice profiles. Higher maximum bulk densities, occurring at the 0.10 to 0.15 m depth of the profiles, may indicate increased subsidence due to cultivation of these soils. Another explanation may be compaction due to machinery. The decrease in bulk density near the surface may be an effect of tillage, since tilled soil is looser and, therefore, a given mass of soil occupies a greater volume.

The third trend in the distribution of bulk density with depth was exhibited by the Horticulture, Fallow, Vegetable 1, and Vegetable 2 profiles. Maximal bulk densities of about the same magnitude as those in the second group were found at lower depths. In the two vegetable profiles, the depth of maximum bulk density was 0.15 to 0.22 m, while for the Horticulture and Fallow soils it was 0.22 to 0.29 m. Also, the bulk densities at the 0.29 to 0.36 m and 0.36 to 0.43 m depths of the latter soils were significantly higher than those in all other soils at these depths (Table A-5). This could be the result of increased subsidence due to intensive cultivation to a greater depth than in the soils in the second group.

Since the bulk density was variable with depth and between fields, and the cores were sectioned by depth, it was decided to express the concentrations of the elements studied on a soil volume basis.

Soil Reaction

The distribution of soil pH with depth for each field sampled is shown in Fig. 5. Values determined for all fields and depths ranged from pH 4.51 to pH 7.30. Trends in the change of pH with depth were similar in the Virgin, Pasture 1, Pasture 2, Pasture 3, and Cane 1

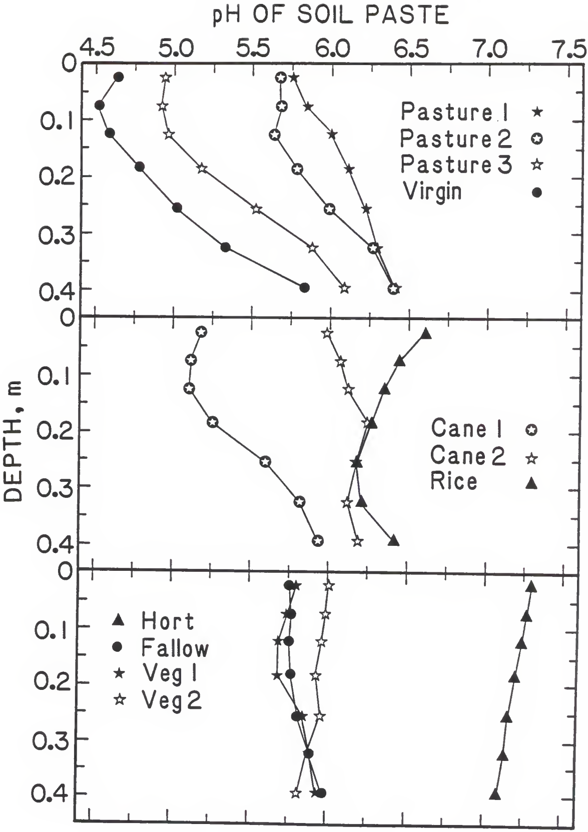


Fig. 5. The pH of Pahokee muck from 11 fields sampled at seven depths.

fields. In these fields, the pH increased sharply with depth, especially below 0.15 m. This may have been an effect of irrigation by water moving up through the soil profile from the underlying limestone bedrock. The pH of the Cane 1, Vegetable 1, and Fallow fields increased slightly with increasing depth. That of the Rice paddy initially decreased from pH 6.60 at the surface to pH 6.18 at 0.22 to 0.29 m and then increased to pH 6.42 at 0.36 to 0.43 m. This may have been due to flooding of the paddy with alkaline water during the growth of the rice. The pH of the Vegetable 2 and Horticulture fields decreased slightly from a maximum at the surface to a minimum at the 0.36 to 0.43 m depth.

Analysis of variance (Table A-32) indicated that there was a very highly significant difference between the means of soil pH and that 90% (r^2=0.90) of the variation in the data was accounted for. Although the field x depth interaction was not significant, the main effects of field and depth were both significant at the 0.1% level. The differences between the means of the main effects were further investigated.

Mean pH of Fields

The mean pH of the profiles from the Virgin area was pH 4.95, which was significantly lower than values from all of the other fields (Table 6). The mean pH values of the Pasture 3 and Cane 1 fields were also low and were significantly different from those of all other fields. Mean values from the Pasture 2, Vegetable 1, Vegetable 2, and Fallow fields fell in the range of pH 5.80 to 5.94 and were not significantly different from each other. The mean soil reaction of the Cane 2 field was pH 6.13, which was not significantly higher than mean pH values found in the Pasture 2 and Vegetable 1 fields. In the Rice paddy, the mean pH of

Table 6. Main effects of fields and depths on pH of soil paste from Pahokee muck.

Field	pH†	Depth	pH†
		m	
Pasture 1	6.09 c	0 to 0.05	5.78 cd
Pasture 2	5.92 cd	0.05 to 0.10	5.76 d
Pasture 3	5.35 e	0.10 to 0.15	5.76 d
Virgin	4.95 f	0.15 to 0.22	5.83 cd
Cane 1	5.43 e	0.22 to 0.29	5.95 bc
Cane 2	6.13 c	0.29 to 0.36	6.07 ab
Rice	6.35 b	0.36 to 0.43	6.19 a
Fallow	5.82 d		
Horticulture	7.20 a		
Vegetable 1	5.94 cd		
Vegetable 2	5.80 d		

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

6.35 was significantly lower than that found in the Horticulture field and was also significantly higher than values determined for the rest of the fields. The highest mean value was pH 7.20, which was found in the Horticulture field. This value was significantly different from values for all other fields. The last observation may have been due to the presence of calcium carbonate particles in the soil samples. The origin of this material is not known, but it may have been introduced during construction of ditches or during deep plowing.

Mean pH with Depth

The mean pH of all fields ranged from pH 5.76 to 5.83 in the top 0.22 m of the profiles (Table 6). Values in the 0 to 0.05 m and 0.15 to 0.22 m depths were not significantly different from the mean pH of 5.95 determined for the 0.22 to 0.29 m depths. A mean pH of 6.07 for the 0.29 to 0.36 m depths was not significantly different from values in the 0.22 to 0.29 m and 0.36 to 0.43 m depths. The highest mean value was pH 6.19 and it occurred at the lowest (0.36 to 0.43 m) depth.

Ash Content

The values of ash content expressed on a soil volume basis ranged from 16.4 to 95.8 kg m^{-3}. Analysis of variance (Table A-32) indicated that there was a very highly significant difference between the ash contents. In addition, there was a very highly significant field x depth interaction and 89% of the variation in the data was accounted for by the model. The distribution of ash content with depth for each field is shown in Fig. 6 and the associated differences between either

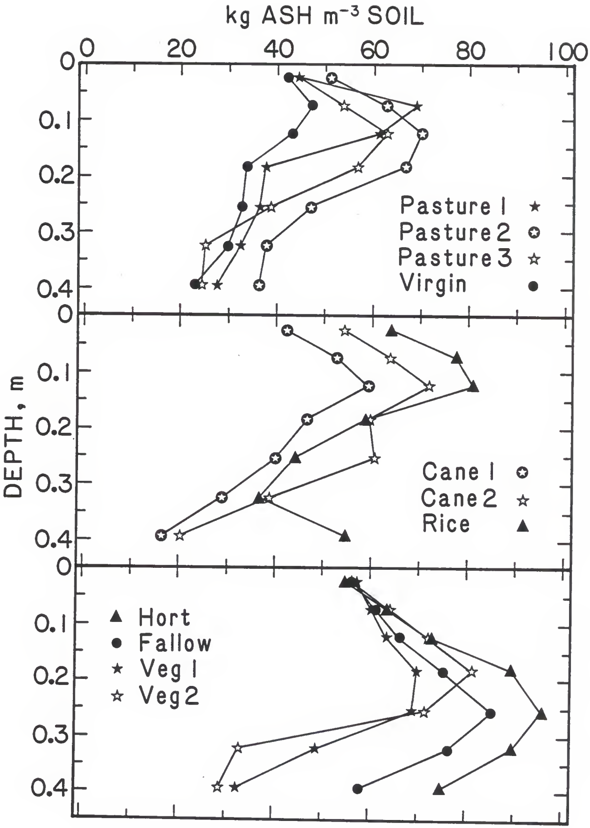


Fig. 6. Weight of ash per unit volume of Pahokee muck from 11 fields sampled at seven depths.

depths within a field or fields at each depth appear in Table A-6. Although values in each of the five depths from 0 to 0.29 m in the Virgin soil tended to be lower than corresponding values in other fields, they were not significantly less. In general, the data for ash content on a soil volume basis reflect those for bulk density (Fig. 4, Table A-5) and do not define changes with depth due to subsidence or soil management in themselves.

Volumetric Water Content

The percent volumetric water contents shown in Fig. 7 and tabulated in Table A-7 represent those existing after a dry season in the Everglades. The samples were taken above the water table and values of volumetric water ranged from 29.5 to 86.2%. There was a very highly significant field x depth interaction and the statistical model accounted for 93% of the variation in the data (Table A-32). To a depth of 0.15 m, the Virgin, Fallow, Horticulture, Vegetable 1, and Vegetable 2 fields had similar low volumetric moisture contents, whereas the remainder of the fields had much higher values. Within the surface 0.15 m of all fields, the moisture content increased with depth and values in the 0 to 0.05 m and 0.10 to 0.15 m depths were significantly different in all but the Pasture 3, Fallow, and Vegetable 2 fields (Table A-7). Below 0.15 m, the volumetric water content in the Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields continued to increase with depth. In the remaining fields, it decreased at 0.15 to 0.22 m, and then again increased with depth below 0.22 m (Fig. 7). However, this decrease was significant in only the Pasture 3 and Cane 2 fields. Below 0.22 m within a soil, there was a significant difference

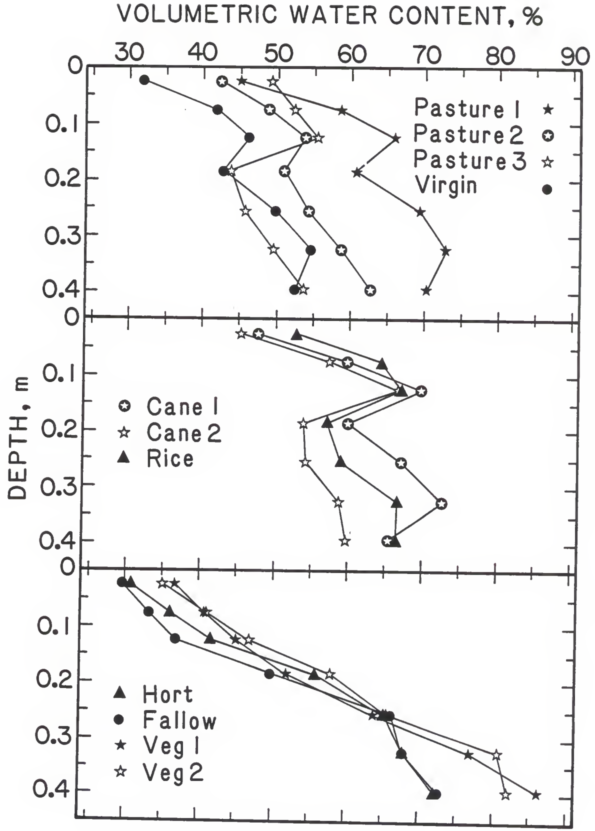


Fig. 7. Volumetric water content of Pahokee muck from 11 fields sampled at seven depths.

in the volumetric water content only in the Cane 2, Vegetable 1, and Vegetable 2 fields. The generally lower volumetric water content in the surface 0.15 m of the Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields, and the distinct difference in distribution of volumetric water content in these fields, may have been the result of tillage before sampling. Homogenization of the soil and increased aeration would tend to disrupt an existing pattern of soil water content and increase loss by evaporation.

Phosphorus Partitioning

A summary of the categories of soil P partitioned appears in Table 7. Inorganic P was independently extracted by water, double acid, or hot 0.1N HCl. Total P was determined in both the hot 0.1N HCl extract and the soil. Total organic P is defined as the difference between total P in the soil and inorganic P extracted by hot 0.1N HCl. Organic P extracted by hot 0.1N HCl is the difference between the total P extracted and inorganic P determined in the hot 0.1N HCl extracts. Residual organic P is organic P not extractable by hot 0.1N HCl and is calculated as the difference between total P in the soil and total P extracted by hot 0.1N HCl.

A comparison of model factors for the various categories of soil P appears in Table 8. Field x depth interactions were not significant for inorganic P extracted by water, double acid, or hot 0.1N HCl, and residual organic P. The main effects of field and depth were highly significant for these categories of soil P. These results were not affected by the expression of values on either a soil weight or soil volume basis (Table 8). Significant field x depth interactions, at the

Table 7. Summary of definitions for categories of soil P.

Category of soil P
Inorganic P extracted by water[†]
Inorganic P extracted by double acid
Total P extracted by hot 0.1N HCl
Inorganic P extracted by hot 0.1N HCl
Organic P extracted by hot 0.1N HCl[‡]
Total P by ashing
Total organic P[§]
Residual organic P[¶]

[†] Determined after clearing the color from the water extracts with activated carbon.

[‡] Obtained by difference between total P extracted by hot 0.1N HCl and inorganic P extracted by hot 0.1N HCl.

[§] Obtained by difference between total P by ashing and inorganic P extracted by hot 0.1N HCl.

[¶] Obtained by difference between total P by ashing and total P extracted by hot 0.1N HCl.

Table 8. Comparison of model factors for various categories of soil P from samples of Pahokee muck.

	Category of soil P							
	Inorganic P by			Organic P			Total P by	
Factor†	Water	DA	HCl	by HCl	Total	Residual	HCl	Ash
r^2								
w/w	0.78	0.73	0.74	0.87	0.94	0.74	0.79	0.86
w/v	0.84	0.78	0.79	0.87	0.90	0.78	0.84	0.87
CV								
w/w	70	87	74	35	15	49	55	35
w/v	56	78	68	38	24	53	51	35
Fields (F)								
w/w	***	***	***	NA	NA	***	***	NA
w/v	***	***	***	NA	NA	***	NA	NA
Depths (D)								
w/w	***	***	***	NA	NA	***	***	NA
w/v	***	***	***	NA	NA	***	NA	NA
FxD‡								
w/w	NS	NS	NS	***	***	NS	NS	***
w/v	NS	NS	NS	***	***	NS	*	***

† r^2, CV, NA, NS, *, and *** are coefficient of determination, coefficient of variation, not applicable, not significant, significant at the 5% level, and significant at the 0.1% level, respectively.

‡ If the FxD interaction was not significant, then differences between field means (averaged over depths) and between depth means (averaged over fields) were further analyzed. Otherwise, differences between fields at each depth and between depths within each field were further analyzed.

0.1% level, were found for total organic P and organic P extracted by hot 0.1N HCl. Again, either basis of expression of the values did not affect the results of the analysis of variance. However, when the values of total P extracted by hot 0.1N HCl were expressed on a soil weight basis, the field x depth interaction was not significant and the main effects of field and depths were significant at the 0.1% level. When the values for this category of soil P were expressed on a soil volume basis, the field x depth interaction was significant at the 5% level.

Inorganic P Extracted by Water

The values of inorganic P extracted with water from the samples of Pahokee muck studied ranged from 0.61 to 25.2 g P m^{-3}. The distribution of water-extractable inorganic P with depth for fields is shown in Fig. 8. In general, values decreased with depth in all fields. Much higher levels of water-extractable inorganic P occurred in the surface 0.10 m of Pasture 1 than at lower depths of this field and may have resulted from the deposition of excreta by grazing cattle. The levels of water-extractable inorganic P in the Horticulture field were much higher throughout the profile than those in the other fields, with the exception of Pasture 1. Analysis of variance indicated that 84% of the variation in the data was accounted for by the model (Table 8). The computed level of significance for the depth x field interaction was 5.43%, which was taken as not significant. However, the differences in means between depths within a field and between fields at each depth were analyzed for this borderline case and appear in Table A-9. Although the field x depth interaction was not significant, the main effects of field and depth were both significant at the 0.1% level (Table 8).

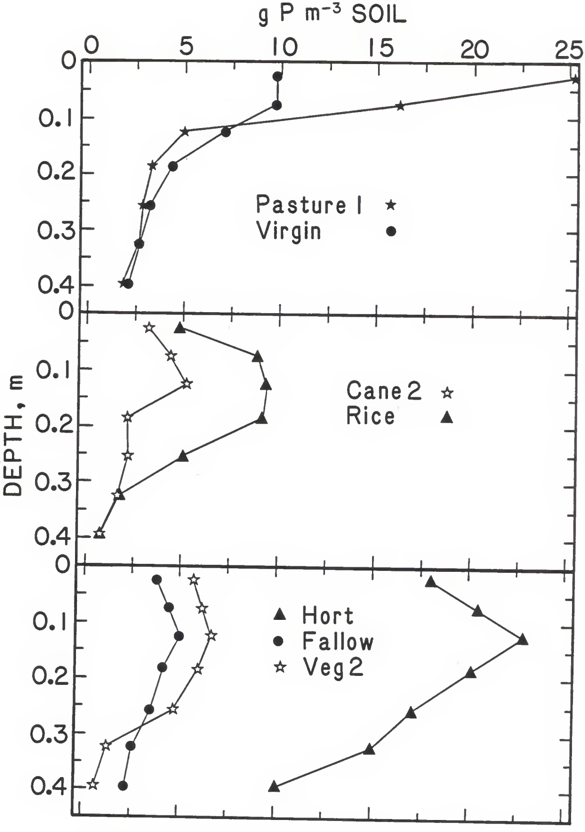


Fig. 8. Inorganic P extracted by water from Pahokee muck from seven fields sampled at seven depths.

The differences between the means for each field and at each depth were further investigated.

Mean water-extractable inorganic P by fields

The highest value of water-extractable inorganic P was 17.7 g P m^{-3} and it occurred in the Horticulture field (Table 9). This value was significantly higher than those of all other fields and reflects a higher level of phosphorus availability in this field. Mean values of water-extractable inorganic P in the Pasture 1, Virgin, and Rice soils were 8.10, 5.56, and 5.67 g P m^{-3}, respectively, and were not significantly different from each other. Low average values of 2.79 to 4.45 g P m^{-3} were determined for the Cane 2, Fallow, and Vegetable 2 fields. These values were not significantly different from each other nor from values for the Virgin and Rice fields.

Mean water-extractable inorganic P by depths

Mean values of water-extractable inorganic P decreased gradually with depth from 10.1 g P m^{-3} at the 0 to 0.05 m depths to 2.63 g P m^{-3} at 0.36 to 0.43 m (Table 9). There was no significant difference between the values of the three depths in the top 0.15 m. Values in the 0.10 to 0.15 m and 0.15 to 0.22 m depths were not significantly different from each other nor were those in the 0.15 to 0.22 m and 0.22 to 0.29 m depths. The mean amounts of inorganic P extracted by water from the three depths from 0.22 to 0.43 m were also not significantly different from each other.

Table 9. Main effects of fields and depths on inorganic P extracted by water from Pahokee muck.

Field	Extracted P†	Depth	Extracted P†
	$g\ m^{-3}$	m	$g\ m^{-3}$
Pasture 1	8.10 b	0 to 0.05	10.10 a
Virgin	5.56 bc	0.05 to 0.10	10.00 a
Cane 2	2.79 c	0.10 to 0.15	8.72 ab
Rice	5.67 bc	0.15 to 0.22	6.94 bc
Fallow	3.68 c	0.22 to 0.29	5.51 cd
Horticulture	17.70 a	0.29 to 0.36	4.02 d
Vegetable 2	4.45 c	0.36 to 0.43	2.63 d

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

Associated determinations on the water extracts

The depth distributions of Ca, Mg, and K, extractable by water, for each field studied appear in Fig. A-1, A-2, and A-3, respectively. The pH of the water extracts, averaged by field and by depth, appears in Table A-8. Values of Ca, Mg, and Fe extracted by water are tabulated in Table A-10, A-11, and A-13, respectively. Water-extractable K, averaged by field and depth, appears in Table A-12.

Inorganic P Extracted by Soil Test Double Acid

The values of inorganic P extracted by double acid from samples of Pahokee muck studied ranged from 4.00 to 350 g P m^{-3}. The distribution of double acid-extractable inorganic P with depth for fields is shown in Fig. 9. In general, values decreased with depth in all fields in much the same manner as did those for water-extractable inorganic P (Fig. 8). Data from Pasture 1, Pasture 2, and Pasture 3 reflect the distribution shown by the water-extractable inorganic P in Pasture 1. Levels of inorganic P extracted by double acid from all depths of the Horticulture field were higher than those from corresponding depths in the other fields. Analysis of variance indicated that the field x depth interaction was not significant, but that the main effects of field and depth were very highly significant (Table 8). The statistical model accounted for 78% of the variation in the data. The differences in the means of the main effects were further analyzed.

Mean double acid-extractable inorganic P by fields

The highest mean value of double acid-extractable inorganic P was 297 g P m^{-3}, which occurred in the Horticulture field, and it was

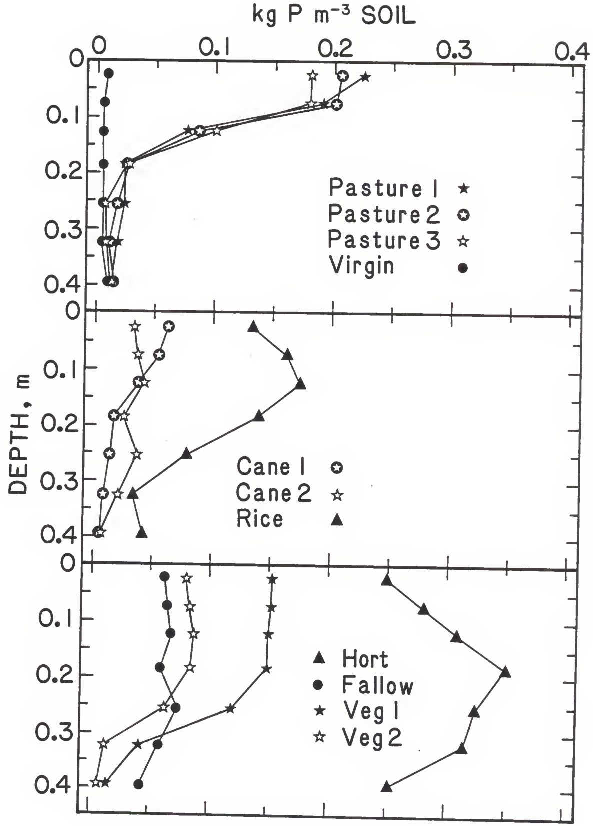


Fig. 9. Inorganic P extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

significantly higher than values in all other fields (Table 10). Lower values of 108 and 111 g P m^{-3}, which were not significantly different from each other, were determined for the Rice and Vegetable 1 fields, respectively. Very similar values of 80.4, 80.5, and 72.6 g P m^{-3} were found in Pasture 1, Pasture 2, and Pasture 3, respectively. These amounts were not significantly different from each other nor from lower values of 27.5, 28.0, 61.4, and 59.4 g P m^{-3} in the Cane 1, Cane 2, Fallow, and Vegetable 2 fields, respectively. The four means of double acid-extractable inorganic P just mentioned were not significantly different from the lowest value of 6.16 g P m^{-3}, which occurred in the Virgin soil.

Mean double acid-extractable inorganic P by depths

Mean values of double acid-extractable inorganic P gradually decreased with depth from 126 g P m^{-3} at the 0 to 0.05 m depth to 37.5 g P m^{-3} at 0.36 to 0.43 m (Table 10). There was no significant difference between those for the three depths in the surface 0.15 m. Values for the three depths from 0.10 to 0.29 m were also not significantly different from each other. No significant difference was found between the contents of the three depths from 0.15 to 0.22 m. This was also the case with values for the three lowest depths.

Associated determinations on the double acid extracts

Values of Ca, Al, Fe, and Cu extracted by double acid are tabulated in Table A-14, A-15, A-16, and A-17, respectively. A summary of the analysis of variance for Ca, Fe, and Cu extracted by double acid appears in Table A-33. The distribution of double acid-extractable Fe with depth

Table 10. Main effects of fields and depths on inorganic P extracted by double acid from Pahokee muck.

Field	Extracted P†		Depth	Extracted P†	
	$g\ m^{-3}$		m	$g\ m^{-3}$	
Pasture 1	80.4	bc	0 to 0.05	126	a
Pasture 2	80.5	bc	0.05 to 0.10	128	a
Pasture 3	72.6	bc	0.10 to 0.15	103	ab
Virgin	6.16	d	0.15 to 0.22	81.7	bc
Cane 1	27.5	cd	0.22 to 0.29	68.3	bcd
Cane 2	28.0	cd	0.29 to 0.36	48.8	cd
Rice	108	b	0.36 to 0.43	37.5	d
Fallow	61.4	bcd			
Horticulture	297	a			
Vegetable 1	111	b			
Vegetable 2	59.4	bcd			

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

for fields is shown in Fig. 10. There was a very noticeable difference between the distribution of double acid-extractable Fe in the Rice and Cane 2 soils compared to those in all other fields. In the Rice field, high values of 540 and 510 kg Fe m^{-3} at the 0.10 to 0.15 m and 0.15 to 0.22 m depths, respectively, were significantly different from levels determined for all other depths of this soil or for corresponding depths in all other fields (Table A-16). In Cane 2, the maximum value of 390 kg Fe m^{-3} occurred at 0.22 to 0.29 m and was significantly higher than all other values determined in this field. However, this value was not significantly different from the 330 kg Fe m^{-3}, at the same depth of the Rice soil. Both of these values were significantly higher than those determined at this depth in all other fields. The reason for these distinctly high levels of double acid-extractable Fe is not clear. Re-examination of the distribution of double acid-extractable inorganic P (Fig. 9) did not reveal similar trends in these data.

Inorganic P Extracted by Hot 0.1N HCl

The values of inorganic P extracted by hot 0.1N HCl from the samples of Pahokee muck ranged from 13.4 to 621 g P m^{-3}. The distribution of hot 0.1N HCl-extractable inorganic P with depth for fields is shown in Fig. 11. These data were distributed closely alike those for both water-extractable and double acid-extractable inorganic P (Fig. 8 and 9, respectively). The statistical model accounted for 79% of the variation in the data and the field x depth interaction was not significant (Table 8). Variability was 68% for this method compared to 56% and 70% encountered for water-extractable inorganic P and double acid-extractable inorganic P, respectively. Differences between the means of the very highly significant main effects were investigated.

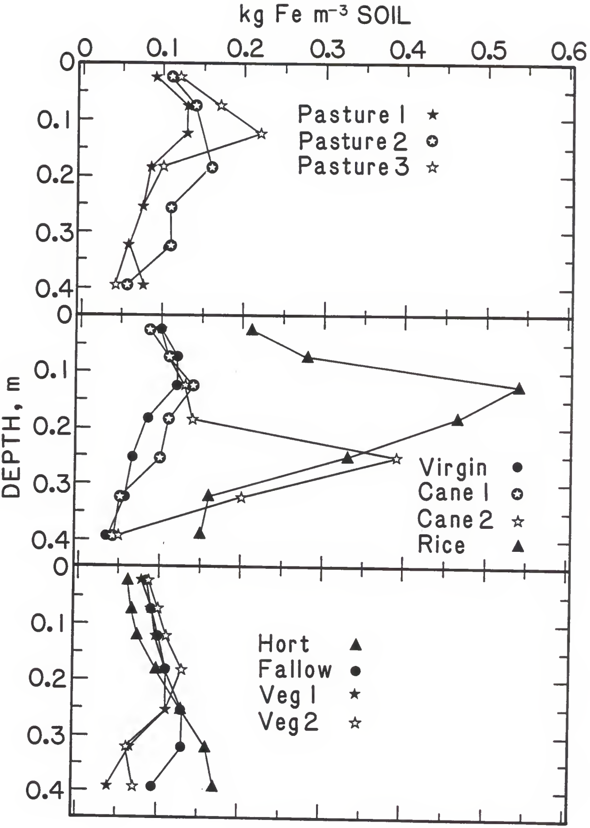


Fig. 10. Iron extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

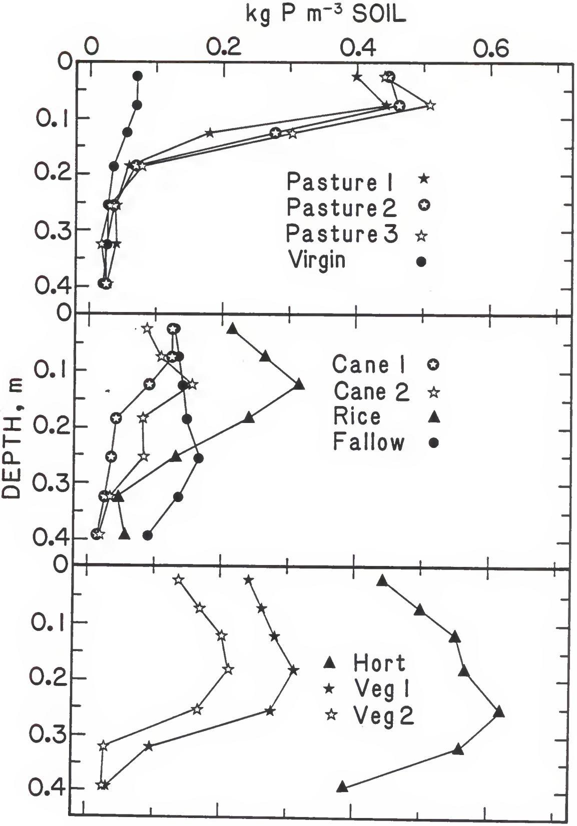


Fig. 11. Inorganic P extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

Mean hot 0.1N HCl-extractable inorganic P by fields

A significantly high level of inorganic P, 519 g P m^{-3}, was extracted from the Horticulture field by hot 0.1N HCl (Table 11). Lower values, which ranged from 134 to 214 g P m^{-3}, were not significantly different from each other and these occurred in the Pasture 1, Pasture 2, Pasture 3, Rice, Fallow, Vegetable 1, and Vegetable 2 fields. The Virgin soil had the lowest value of inorganic P, 43.5 g P m^{-3}, but it was not significantly different from those in the Cane 1, Cane 2, Fallow, and Vegetable 2 fields.

Mean hot 0.1N HCl-extractable inorganic P by depths

The mean values of inorganic P extracted by hot 0.1N HCl decreased with depth from 0.05 to 0.43 m (Table 11). Values of 248, 277, and 232 g P m^{-3} in the 0 to 0.05 m, 0.05 to 0.10 m, and 0.10 to 0.15 m depths were not significantly different from each other. Similarly, values were not significantly different from each other in the depths from either 0.10 to 0.22 or 0.15 to 0.36 m. The lowest value of inorganic P extracted was 64.8 g P m^{-3} at 0.36 to 0.43 m, but it was not significantly different from that at the 0.29 to 0.36 m depth.

Total P Extracted by Hot 0.1N HCl

The range of total P extracted from the samples of Pahokee muck studied was from 26.1 to 861 g P m^{-3}. The depth distribution, for fields, of total P extracted by hot 0.1N HCl is shown in Fig. 12. In general, these data reflect those for inorganic P extractable by water, double acid, and hot 0.1N HCl (Fig. 8, 9, and 11, respectively). High levels of total P were extracted from the surface 0.10 m of the

Table 11. Main effects of fields and depths on inorganic P extracted by hot 0.1N HCl from Pahokee muck.

Field	Extracted P†	Depth	Extracted P†
	g m^{-3}	m	g m^{-3}
Pasture 1	169 bc	0 to 0.05	248 a
Pasture 2	192 b	0.05 to 0.10	277 a
Pasture 3	200 b	0.10 to 0.15	232 ab
Virgin	43.5 d	0.15 to 0.22	167 bc
Cane 1	64.6 d	0.22 to 0.29	147 c
Cane 2	80.6 cd	0.29 to 0.36	93.8 cd
Rice	180 b	0.36 to 0.43	64.8 d
Fallow	135 bcd		
Horticulture	519 a		
Vegetable 1	214 b		
Vegetable 2	134 bcd		

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

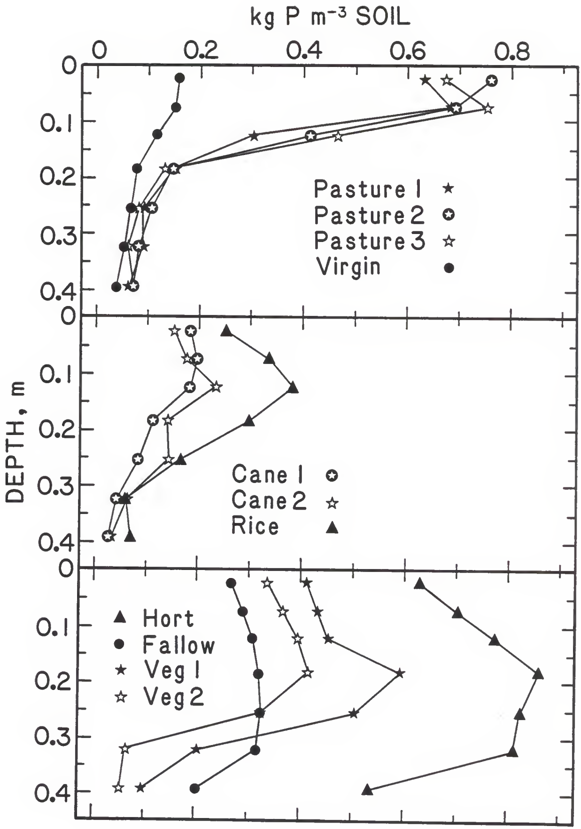


Fig. 12. Total P extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

three pastures and throughout the Horticulture profile. The field x depth interaction for total P extracted by hot 0.1N HCl was significant at the 5% level and 84% of the variation in the data was explained by the model (Table 8). Further analysis of the differences between total P extracted from depths within each field and those between fields at each depth was conducted (Table A-18).

Changes in hot 0.1N HCl-extractable total P with depth by fields

In Pasture 1, the maximum total P extracted by hot 0.1N HCl was 683 g P m^{-3} from soil at the 0.05 to 0.10 m depth. This was not significantly different from the total P extracted at the 0.05 to 0.10 m depth. Both of these values were significantly higher than those at lower depths. The latter decreased from 149 g P m^{-3} at 0.15 to 0.22 m to 63.3 g P m^{-3} at 0.36 to 0.43 m.

In Pasture 2, a total of 759 g P m^{-3} was extracted from the top 0.05 m by hot 0.1N HCl. This was significantly higher than all values in the lower depths of this field. At the 0.05 to 0.10 m depth, 689 g P m^{-3} were extracted. This value was significantly higher than those determined for the four depths from 0.15 to 0.32 m, which decreased from 148 to 70.5 g P m^{-3} and were not significantly different from each other.

In Pasture 3, a maximum of 752 g P m^{-3} was extracted by hot 0.1N HCl from soil at 0.05 to 0.10 m. This value was not significantly different from those determined for the two other depths from 0 to 0.15 m, but all three were significantly higher than those at lower depths. The latter values decreased from 132 g P m^{-3} at 0.15 to 0.22 m to 70.2 g P m^{-3} at 0.36 to 0.43 m and were not significantly different from each other.

In the Virgin soil, total P extracted by hot 0.1N HCl decreased from 158 g P m^{-3} in the surface 0.05 m to 37.2 g P m^{-3} at the 0.36 to 0.43 m depth. However, there was no significant difference between these values with depth. Similarly, there was no significant difference between total P extracted by hot 0.1N HCl from soil at the seven depths within each of the Cane 1, Cane 2, Rice, Fallow, and Horticulture fields, even though total P was different between fields (Fig. 12).

In the Vegetable 1 field, the maximum value of 593 g P m^{-3} was extracted from soil at the 0.15 to 0.22 m depth. This was not significantly higher than those from either the three depths from 0 to 0.15 m nor the 0.22 to 0.29 m depth. Levels of total P extracted from the latter depths were not significantly higher than that from the 0.29 to 0.36 m depth. Total P extracted at 0.29 to 0.36 m was 203 g P m^{-3}, while that at 0.36 to 0.43 m was 94.3 g P m^{-3}. These values were not significantly different from each other.

In the Vegetable 2 field, soil at the 0.15 to 0.22 m depth had the most total P extracted with hot 0.1N HCl. However, values for the five depths from 0 to 0.29 m ranged from 325 to 415 g P m^{-3} and were not significantly different from each other. Low values occurred in the two depths below 0.29 m, but these were not significantly different from that extracted from soil at 0.22 to 0.29 m.

Changes in hot 0.1N HCl-extractable total P with field by depths

At the 0 to 0.05 m depth, the maximum total P extracted by hot 0.1N HCl was 759 g P m^{-3} in Pasture 2. It was not significantly higher than the values of 631, 672, and 629 g P m^{-3}, determined for Pasture 1, Pasture 3, and the Horticulture field, respectively. In the Vegetable 1 field at this depth, a total of 410 g P m^{-3} was extracted, but this value was significantly different only from the maximum found in Pasture 2. The minimum value of total P extracted was 151 g P m^{-3} in the Cane 2 field. This value was not significantly lower than those determined for the Virgin, Cane 1, Rice, Fallow, and Vegetable 2 fields at this depth.

At 0.05 to 0.10 m, the maximum total P, 752 g P m^{-3}, was extracted from Pasture 3, but this value was not significantly higher than those, which ranged from 432 to 703 g P m^{-3}, in the Pasture 1, Pasture 2, Horticulture, and Vegetable 1 fields. The minimum amount of total P extracted by hot 0.1N HCl at this depth was 151 g P m^{-3} in the Virgin field, but this value was not significantly different from those in the Cane 1, Cane 2, Rice, Fallow, Vegetable 1, and Vegetable 2 fields.

At the 0.10 to 0.15 m depth, a significantly high value of total P, 774 g P m^{-3}, was extracted by hot 0.1N HCl from the Horticulture field. Levels extracted from the Pasture 1, Pasture 2, Pasture 3, Cane 1, Cane 2, Rice, Fallow, Vegetable 1, and Vegetable 2 fields were not significantly different. At this depth, the Virgin field contained the minimum of 114 g P m^{-3}. This value was significantly lower than those in Pasture 3 and the Horticulture fields.

At 0.15 to 0.22 m, the maximum total P extracted was 861 g P m^{-3} in the Horticulture field. The value of total P extracted from this depth of the Vegetable 1 field was not significantly lower. Values ranging from 297 to 593 g P m^{-3} in the Rice, Fallow, Vegetable 1, and Vegetable 2 fields were not significantly different from each other. The minimum total P extracted from this depth by the reagent was 76.2 g P m^{-3} from the Virgin field. This value was significantly lower than those determined for the Horticulture and Vegetable 1 fields.

At the 0.22 to 0.29 m depth, a significantly high maximum of 826 g P m^{-3} was extracted from the Horticulture field. In the Fallow, Vegetable 1, and Vegetable 2 fields, values of 324, 506, and 325 g P m^{-3}, respectively, did not differ significantly. At this depth, a minimum of 65.7 g P m^{-3} was extracted by hot 0.1$\underline{N}$ HCl from the Virgin field and this was significantly different from values determined for the Horticulture and Vegetable 1 fields.

At 0.29 to 0.36 m, the maximum total P extracted was 812 g P m^{-3} from the Horticulture field. This was significantly higher than the values determined for all other fields at this depth. The minimum level of total P was extracted from the Cane 1 field and this was 42.3 g P m^{-3}.

At 0.36 to 0.43 m, total P extracted by hot 0.1$\underline{N}$ HCl from the Horticulture field was 534 g P m^{-3}. Significantly lower levels of total P were extracted from all other fields at this depth. These ranged from 26.1 to 199 g P m^{-3} and the minimum value occurred in the Cane 1 field.

Organic P Extracted by Hot 0.1N HCl

The range of organic P extracted from the samples of Pahokee muck by hot 0.1$\underline{N}$ HCl was 12.1 to 321 g P m^{-3}. The depth distribution of organic P extracted is shown by fields in Fig. 13. High levels of organic P were extracted from the surface 0.10 m of Pasture 1, Pasture 2, and Pasture 3. The field x depth interaction was very highly significant and the statistical model explained 87% of the variation in these data (Table 8). Differences between organic P extracted from either depths within each field or fields at each depth were analyzed (Table A-19). Data for total organic P are discussed in a later section.

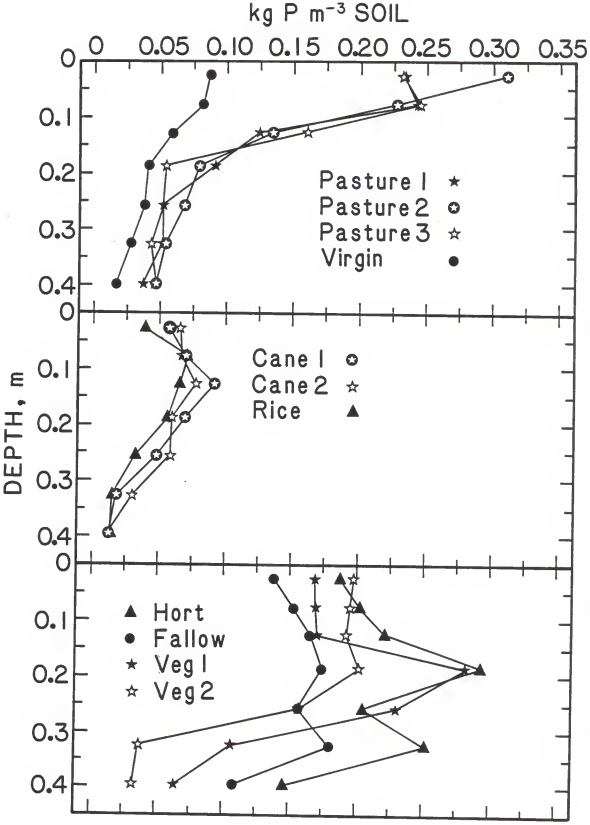


Fig. 13. Organic P extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

Changes in hot 0.1N HCl-extractable organic P with depth by fields

In Pasture 1, the maximum organic P extracted was 242 g P m^{-3} at the 0.05 to 0.10 m depth. Although this value was not significantly higher than that at 0 to 0.05 m, both were significantly higher than all other values determined below 0.10 m in this field. The latter decreased from 124 to 36.8 g P m^{-3} with depth and did not differ significantly.

In Pasture 2, organic P extracted from the top 0.05 m was 310 g P m^{-3}. This maximum value was not significantly higher than that determined for 0.05 to 0.10 m depth. Below 0.10 m, organic P extracted by hot 0.1N HCl decreased with depth from 134 to 46.4 g P m^{-3}. These values did not differ significantly from each other, but were significantly lower than those in the two top depths.

In Pasture 3, organic P extracted from the 0.05 to 0.10 m depth was 245 g P m^{-3}, which was not significantly higher than that at either the 0 to 0.05 m or 0.10 to 0.15 m depths. However, the levels of organic P extracted from the aforementioned depths were significantly higher than those determined for depths below 0.15 m. The latter fell in the narrow range of 53.7 to 45.5 g P m^{-3}.

In the Virgin soil, organic P extracted decreased with depth from 86.1 to 16.8 g P m^{-3}. There was no significant difference between these values.

In the Cane 1 field, organic P extracted by hot 0.1N HCl increased from 57.4 g P m^{-3} for the surface 0.05 m to 91.6 g P m^{-3} for the 0.10 to 0.15 m depth and then decreased to 12.7 g P m^{-3} for the lowest depth sampled. None of these values were significantly different.

In the Cane 2 field, the level of organic P extracted increased slightly with depth from 57.4 g P m^{-3} in the surface 0.05 m of soil to 77.4 g P m^{-3} at 0.10 to 0.15 m. Below 0.15 m, values decreased to 12.1 g P m^{-3}, but there was no significant difference between any of these values.

In the Rice paddy, the maximum organic P extracted by hot 0.1N HCl was 71.2 g P m^{-3} from soil at the 0.05 to 0.10 m depth. Although the top 0.05 m contained 38.5 g P m^{-3} and values decreased with depth from the maximum to 13.5 g P m^{-3} at 0.36 to 0.43 m, there was no significant difference between any of these values.

In the Fallow field, values of extractable organic P ranged from 108 to 180 g P m^{-3}, but there was no significant difference between these values.

In the Horticulture field, the level of extractable organic P was 293 g P m^{-3} in the 0.15 to 0.22 m depth. This maximum was not significantly higher than values ranging from 202 to 252 g P m^{-3} in all other depths from 0.10 to 0.36 m. The minimum of 146 g P m^{-3} extracted at 0.36 to 0.43 m was significantly lower than values of organic P extracted at 0.15 to 0.22 m and 0.29 to 0.36 m.

In the Vegetable 1 field, the maximum extractable organic P was 282 g P m^{-3} at 0.15 to 0.22 m. Significantly lower values occurred above 0.15 m. A level of 230 g P m^{-3} at 0.22 to 0.29 m was not significantly lower than the maximum, but values of 106 and 64 g P m^{-3} at the 0.29 to 0.36 m and 0.36 to 0.43 m depths, respectively, were so.

In the Vegetable 2 field, values of hot 0.1N HCl-extractable organic P ranging from 157 to 202 g P m^{-3} occurred in the five depths from 0 to 0.29 m. These values were not significantly different from each other, but were significantly higher than the values of 36.6 and 32.1 g P m^{-3} determined for the 0.29 to 0.36 m and 0.36 to 0.43 m depth, respectively.

Changes in hot 0.1N HCl-extractable organic P with field by depths

At 0 to 0.05 m, the maximum organic P extracted was 310 g P m^{-3} in Pasture 2. Values determined for Pasture 1 and Pasture 3 were not significantly lower. Values for the latter fields and those for the Fallow, Horticulture, Vegetable 1, and Vegetable 2 fields ranged from 137 to 233 g P m^{-3} and were not significantly different from each other. The Virgin field had 86.1 g P m^{-3} of extractable organic P at this depth. This value was not significantly lower than those in the Fallow, Horticulture, and Vegetable 1 fields nor was it significantly higher than those in the Cane 1, Cane 2, or Rice fields.

At 0.05 to 0.10 m, the highest level of organic P extracted by hot 0.1N HCl was 245 g P m^{-3} from Pasture 3. This value was significantly higher than values occurring in the Virgin, Cane 1, Cane 2, and Rice fields. Values for these fields ranged from 67.0 to 80.7 g P m^{-3} and did not differ significantly from a value of 152 g P m^{-3} determined for the Fallow field.

At the 0.10 to 0.15 m depth, the Horticulture field had the highest content of extractable organic P, which was 221 g P m^{-3}. This was significantly higher than levels determined in the Virgin, Cane 1, Cane 2, and Rice fields at this depth. The Virgin field had the minimum extractable organic P content of 59.0 g P m^{-3}. This was not significantly lower than values ranging from 65.5 to 134 g P m^{-3} in the Pasture 1, Pasture 2, Cane 1, Cane 2, and Rice fields.

At 0.15 to 0.22 m, a maximum of 293 g P m^{-3} in the Horticulture field was significantly higher than values in all other fields except Vegetable 1 and Vegetable 2. Levels of organic P extracted from the Vegetable 2 and Fallow fields were not significantly different, nor were those in Pasture 1 and the Fallow fields. The minimum value of 40.9 g P m^{-3} occurred in the Virgin field and was significantly different from higher values in the Fallow, Horticulture, Vegetable 1, and Vegetable 2 fields.

At the 0.22 to 0.29 m depth, the Vegetable 1 field had the most organic P, 230 g P m^{-3}, extractable with hot 0.1N HCl. This was not significantly higher than values of 156 to 205 g P m^{-3} found in the Horticulture, Fallow, and Vegetable 2 fields and these were not significantly higher than 68.1 g P m^{-3} determined for Pasture 2 at this depth. A minimum of 34.5 g P m^{-3} for extractable organic P occurred in the Rice field. This value was significantly lower than those for the Fallow, Horticulture, Vegetable 1, and Vegetable 2 fields at this depth.

At 0.29 to 0.36 m, a maximum of 252 g P m^{-3} was extracted as organic P from the Horticulture field. This was significantly higher than values occurring in all fields except the Fallow field, from which 180 g P m^{-3} were extracted. This was not significantly different from the value for the Vegetable 1 field. A minimum of 14.5 g P m^{-3} was found for organic P and this occurred in the Rice field. This value was significantly lower than those determined in the Horticulture and Fallow fields.

At 0.36 to 0.43 m, which was the lowest depth sampled, the Horticulture field had the highest level of extractable organic P. This value was 146 g P m^{-3} and it was not significantly higher than values of 108 and 64.0 g P m^{-3} in the Fallow and Vegetable 1 fields. A minimum of 12.1 g P m^{-3} was the estimate of extractable organic P in the Cane 2 field at this depth. This value was significantly lower than that determined in the Horticulture field.

Associated determinations on the hot 0.1N HCl extracts

Data for Ca, Al, Fe, and Cu extracted by hot 0.1N HCl are tabulated in Tables A-20, A-21, A-22, and A-23, respectively. A summary of the analysis of variance for Ca, Fe, and Cu extracted by hot 0.1N HCl appears in Table A-33. The distribution of Ca extracted with depth for fields is shown in Fig. A-4. The depth distribution of extractable Fe for fields is shown in Fig. 14. Trends in the distribution of the Fe data did not resemble those of Fe extractable by double acid (Fig. 10). The reason for this is unclear. In addition, there was little similarity between the distribution of Fe extractable by hot 0.1N HCl and those of the three categories of soil P extracted by this reagent (Fig. 11, 12, and 13). However, trends in the distribution of the hot 0.1N HCl-extractable Fe data with depth for each field (Fig. 14) did resemble those of bulk density (Fig. 4). This indicates a relatively constant content of extractable Fe with depth in each profile.

Total P by Ashing

Total P recovered from ashed samples of Pahokee muck ranged from 45.5 to 879 g P m^{-3}. The distributions of these data with depth for the fields sampled are shown in Fig. 15. High levels of total P occurred in the surface 0.10 m of the three pastures and throughout the Horticulture profile. In general, the distribution of total P found by ashing was similar to that of total P extracted by hot 0.1N HCl (Fig. 12). There was a very highly significant field x depth interaction for total P by ashing and the statistical model explained 87% of the variation in the data (Table 8). Variability in total P determined by ashing was 35% compared to 51% for total P extracted by hot 0.1N HCl. Differences

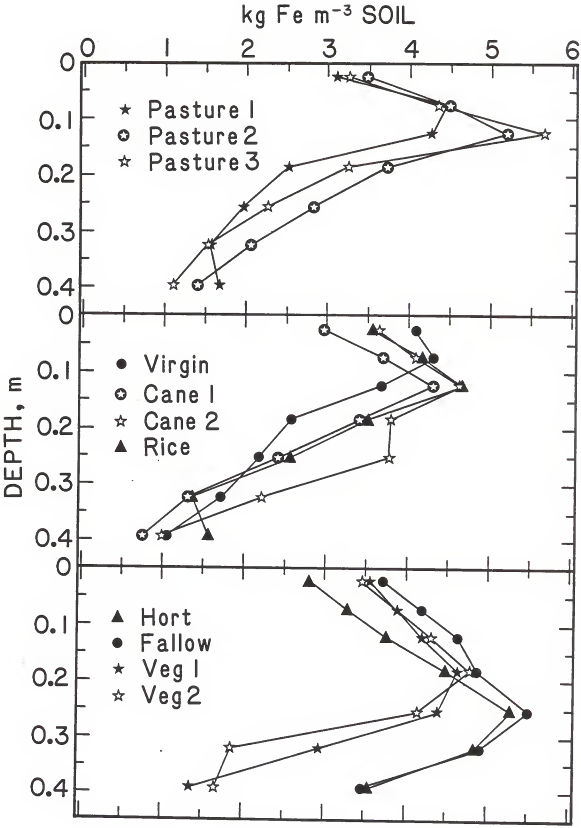


Fig. 14. Iron extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

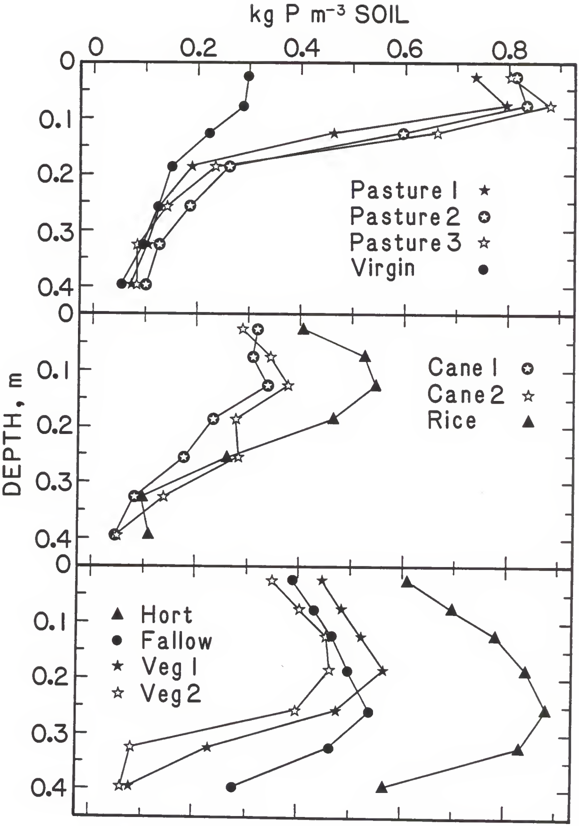


Fig. 15. Total P after ashing of Pahokee muck from 11 fields sampled at seven depths.

in total P by ashing were analyzed for depths within each field and for fields at each depth (Table A-24).

Changes in total P with depth by fields

In Pasture 1, the maximum total P determined after ashing was 759 g P m^{-3} from soil at the 0.05 to 0.10 m depth. This was significantly higher than all values occurring below 0.10 m in this field. The 0.10 to 0.15 m depth had 463 g P m^{-3} and this was significantly higher than those of lower depths. These decreased from 190 g P m^{-3} at 0.15 to 0.22 m to 72.9 g P m^{-3} at 0.36 to 0.43 m, but did not differ significantly.

In Pasture 2, the maximum of 834 g P m^{-3} occurred at 0.05 to 0.10 m. This was not significantly higher than values determined for the two other depths in the top 0.15 m, but all three values were significantly greater than those occurring at depths below 0.15 m. The latter decreased with depth from 262 to 101 g P m^{-3} and did not differ significantly from each other.

In Pasture 3, 879 g P m^{-3} at 0.05 to 0.10 m was the highest level of total P determined by ashing. It was significantly higher than those occurring at depths below 0.15 m. These decreased with depth from 235 to 84.4 g P m^{-3}, but were not significantly different from each other.

In the Virgin field, levels of total P by ashing decreased with depth from 298 to 54.9 g P m^{-3}, but did not differ significantly. Also, in the Cane 1 field, values of total P were significantly different from each other for the seven depths.

In the Cane 2 field, a maximum of 378 g P m^{-3} occurred at 0.10 to 0.15 m and it was significantly higher than 47.4 g P m^{-3} found at

0.36 to 0.43 m. The latter value was not significantly lower than others determined for depths between 0.15 to 0.36 m.

In the Rice paddy, soil at 0.10 to 0.15 m had the maximum value of total P by ashing, and this was 546 g P m^{-3}. This was significantly higher than 95.4 and 110 g P m^{-3}, which were determined for soil at 0.29 to 0.36 m and 0.36 to 0.43 m, respectively. Neither of these values differed significantly from that found at 0.22 to 0.29 m.

In the Fallow field, total P by ashing increased with depth from 391 g P m^{-3} at the top 0.05 m to 540 g P m^{-3} at 0.22 to 0.29 m. It then decreased to 270 g P m^{-3} at 0.36 to 0.43 m. None of these values differed significantly.

In the Horticulture field, values of total P increased with depth from 610 g P m^{-3} at 0 to 0.05 m to 880 g P m^{-3} at 0.22 to 0.29 m. Total P decreased with depth below 0.29 m to 567 g P m^{-3} at 0.36 to 0.43 m. Only the maximum and minimum values of total P were significantly different. The maximum was not significantly higher than the remaining values nor was the minimum significantly lower than those at the remaining depths.

In the Vegetable 1 field, total P determined by ashing increased with depth from 447 g P m^{-3} in the top 0.05 m to a maximum of 556 g P m^{-3} at 0.15 to 0.22 m. These values were not significantly different from 476 g P m^{-3} at 0.29 to 0.36 m. The minimum of 77.2 g P m^{-3} occurred at 0.36 to 0.43 m and was significantly lower than the values in the five depths from 0 to 0.29 m.

In the Vegetable 2 field, levels of total P increased with depth from 350 g P m^{-3} at 0 to 0.05 m to a maximum of 462 g P m^{-3} at 0.15 to 0.22 m. At 0.22 to 0.29 m, total P by ashing was 398 g P m^{-3}. None of the values determined in the five depths from 0 to 0.29 m was significantly different, but all were significantly higher than 79.0 and 59.2 g P m^{-3} at 0.29 to 0.36 m and 0.36 to 0.43 m, respectively. The latter values did not differ from each other significantly.

Changes in total P with field by depths

At the 0 to 0.05 m depth, the maximum of total P determined by ashing was 814 g P m^{-3}. This was found in Pasture 2 and was significantly higher than values in all other fields except the Pasture 1, Pasture 3, and Horticulture fields. Values determined for the Cane 1, Rice, Fallow, and Vegetable 1 fields did not differ significantly from each other. The Cane 2 field had the minimum total P, which was 289 g P m^{-3}. This was significantly lower than determinations for the three pasture and the Horticulture fields.

At 0.05 to 0.10 m, Pasture 3 had 879 g P m^{-3} and this was the maximum of total P for this depth. Values in the Pasture 1, Pasture 2, and Horticulture fields were not significantly lower. Total P in the Rice field did not differ significantly from that in either the Pasture 1 or Horticulture fields. Also, values determined for the Rice, Fallow, Horticulture, and Vegetable 1 fields were not significantly different from each other. The minimum value of total P by ashing was 290 g P m^{-3}, which occurred in the Virgin field. This was significantly lower than values for the three pastures and the Horticulture field.

At the 0.10 to 0.15 m depth, the maximum total P was 781 g P m^{-3} and this occurred in the Horticulture field. This was significantly higher than levels determined in all but the Pasture 2, Pasture 3, Rice, and Vegetable 1 fields. A value of 662 g P m^{-3}, found in Pasture 3, was significantly higher than those in the Cane 1 and Virgin fields. Also, the total P by ashing in Pasture 2 was 596 g P m^{-3}, which was significantly greater than the minimum of 222 g P m^{-3} found in the Virgin field. The latter was significantly different from values determined at this depth for the Pasture 1, Cane 1, Cane 2, Fallow, and Vegetable 2 fields.

At 0.15 to 0.22 m, a maximum of 841 g P m^{-3} was determined for total P. This occurred in the Horticulture field and was significantly higher than all other values at this depth. The Rice, Fallow, Vegetable 1, and Vegetable 2 fields had levels ranging from 462 to 566 g P m^{-3}, but these did not differ significantly. Values of total P determined for the Pasture 2, Pasture 3, Cane 1, Cane 2, Rice, Fallow, and Vegetable 2 fields were not significantly different from each other, nor were those found in the Pasture 1, Pasture 2, Pasture 3, Cane 1, Cane 2, Rice, and Vegetable 2 fields. The minimum total P determined at this depth was 151 g P m^{-3} and this was in the Virgin field. It was significantly less than those determinations for the Rice, Fallow, Horticulture, Vegetable 1, and Vegetable 2 fields at this depth.

At the 0.22 to 0.29 m depth, the maximum value of total P was 880 g P m^{-3}, which occurred in the Horticulture field. This was significantly higher than values determined for all other fields at this depth. Levels found in the Rice, Cane 2, Fallow, Vegetable 1, and Vegetable 2 fields did not differ from each other significantly. A minimum of 124 g P m^{-3} occurred in the Virgin field and was significantly less than values of total P determined by ashing of soil from the Fallow, Horticulture, and Vegetable 1 fields at this depth.

At 0.29 to 0.36 m, the maximum for total P, 829 g P m^{-3}, was determined in the Horticulture field. This value was significantly higher than those found in all other fields at this depth. Levels in the Fallow and Vegetable 1 fields did not differ significantly from each other. The minimum value of 79.0 g P m^{-3} occurred in the Vegetable 2 field and was significantly less than those values in the Horticulture and Fallow fields.

At the 0.36 to 0.43 m depth, the highest level of total P determined by ashing was 567 g P m^{-3}. This was from the Horticulture field and it was significantly higher than determinations for all other fields at this depth. A minimum of 45.5 g P m^{-3} occurred in the Cane 1 field, but it was only significantly less than the maximum value.

Total Organic P

Total organic P was calculated as the difference between total P after ashing and inorganic P extracted by hot 0.1$\underline{N}$ HCl. Values ranged from 30.2 g P m^{-3} to 369 g P m^{-3}. The distributions of these data with depth for fields are shown in Fig. 16. Relatively high levels of total organic P occurred in the surface 0.15 m of the three pastures and in the Fallow field to a depth of 0.29 m. Analysis of variance indicated that there was a very highly significant field x depth interaction (Table 8) and that 90% of the variation in the data was accounted for by the statistical model. Variability in these data was 24% compared to 38% encountered for the organic P extracted by hot 0.1$\underline{N}$ HCl. Further analysis centering on the differences between levels of total organic P from depths within each field or fields at each depth was conducted (Table A-25).

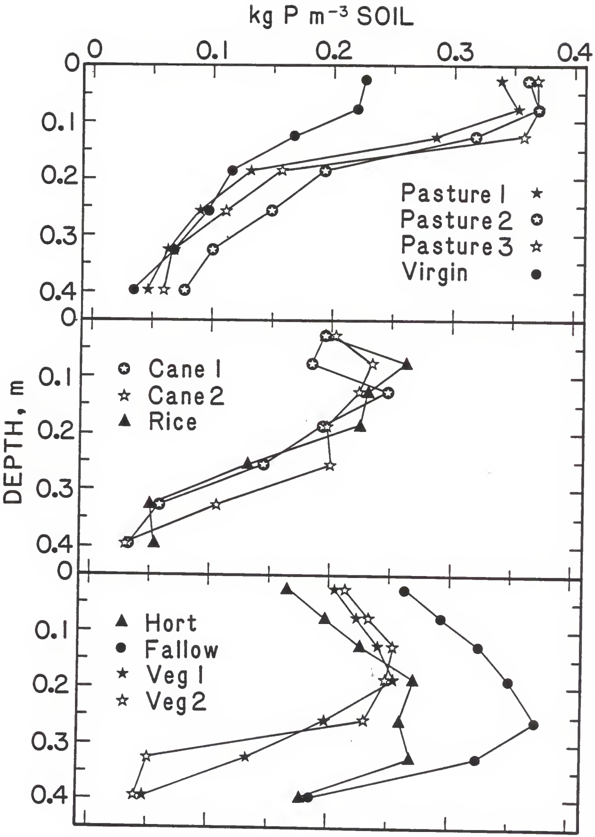


Fig. 16. Total organic P from Pahokee muck from 11 fields sampled at seven depths.

Changes in total organic P with depth by fields

In Pasture 1, the maximum total organic P was 353 g P m^{-3} at the 0.05 to 0.10 m depth. Values of 338 and 285 g P m^{-3} at 0 to 0.05 m and 0.10 to 0.15 m, respectively, were not significantly different from the maximum value. However, they were significantly greater than those below 0.15 m, which decreased with depth from 132 to 46.4 g P m^{-3}. The latter were not significantly different from each other.

In Pasture 2, high values of total organic P were 369 and 370 g P m^{-3} at 0 to 0.05 m and 0.05 to 0.10 m, respectively. The 0.10 to 0.15 m depth had 318 g P m^{-3}, but this was not significantly lower than the former values. Below 0.15 m, levels of total organic P decreased with depth from 193 to 76.9 g P m^{-3}. These values did not differ from each other significantly, but they were significantly lower than those in the top three depths.

In Pasture 3, the 0.10 to 0.15 m depth had the maximum total organic P, which was 371 g P m^{-3}. This was not significantly higher than 362 and 371 g P m^{-3} obtained for the 0 to 0.05 m and 0.10 to 0.15 m depths, respectively. All of these values were significantly higher than values from below 0.15 m, which decreased with depth from 157 to 59.6 g P m^{-3}.

In the Virgin field, total organic P decreased with depth from a maximum of 227 g P m^{-3} in the top 0.05 m to a minimum of 34.5 g P m^{-3} at 0.36 to 0.43 m. Values in the three top depths did not differ significantly. These was no significant difference between estimates of total organic P at the four depths from 0.10 to 0.36 m, nor was there any significant difference between those at the four depths from 0.15 to 0.43 m.

In the Cane 1 field, the 0.10 to 0.15 m depth had the maximum total organic P. This was 247 g P m^{-3}, which was not significantly higher than those at the other three depths in the top 0.22 m of this soil. Below 0.15 m, total organic P decreased with depth from 193 g P m^{-3} at 0.15 to 0.22 m to a minimum of 32.2 g P m^{-3} at 0.36 to 0.43 m. The former was not significantly different from the level of total organic P at 0.22 to 0.29 m, but the minimum was significantly lower than all values in this profile, except for that at 0.29 to 0.36 m.

In the Cane 2 field, the maximum total organic P was 234 g P m^{-3}, which occurred in the 0.05 to 0.10 m depth. Below 0.10 m, total organic P decreased with depth from 223 to 30.2 g P m^{-3}. Values in the five depths from 0 to 0.29 m were not significantly different from each other, nor were those in the three depths from 0.22 to 0.36 m. The minimum, which occurred at 0.36 to 0.43 m was not significantly different from the estimate of 106 g P m^{-3} at 0.29 to 0.36 m, but it was significantly less than those in all other depths of the profile.

In the Rice paddy, the highest value of total organic P was 262 g P m^{-3} and this was found for the 0.05 to 0.10 m depth. Levels at the three other depths from 0 to 0.22 m were not significantly less than the maximum. Values for the 0.15 to 0.22 m and 0.22 to 0.29 m depths were 224 and 131 g P m^{-3}, respectively, but these did not differ significantly from each other. The latter was not significantly higher than 50.2 and 53.7 g P m^{-3}, which occurred at 0.29 to 0.36 m and 0.36 to 0.43 m, respectively.

In the Fallow field, total organic P increased with depth from 263 g P m^{-3} in the top 0.05 m to a maximum of 373 g P m^{-3} at 0.22 to 0.29 m and then decreased with depth to a minimum of 187 g P m^{-3} at

0.36 to 0.43 m. Values in the five depths from 0.05 to 0.36 m were not significantly different from each other, but all were significantly greater than the minimum value at 0.36 to 0.43 m.

In the Horticulture field, total organic P increased with depth from a minimum of 166 g P m^{-3} at 0 to 0.05 m to a maximum of 272 g P m^{-3} at 0.15 to 0.22 m. These two values were significantly different. Levels of 260, 269, and 178 g P m^{-3} at 0.22 to 0.29 m, 0.29 to 0.36 m, and 0.36 to 0.43 m, respectively, were not significantly less than the maximum, nor were estimates for the two depths from 0.05 to 0.15 m. On the other hand, all of these values were not significantly greater than the minimum.

In the Vegetable 1 field, total organic P increased with depth from 205 g P m^{-3} at 0 to 0.05 m to a maximum of 255 g P m^{-3} at 0.15 to 0.22 m. Below 0.22 m there was a decrease in total organic P with depth to a minimum of 46.8 g P m^{-3} at 0.36 to 0.43 m. The maximum value was significantly greater than those values for the two depths below 0.29 m. Values for depths from 0 to 0.10 m and 0.22 to 0.36 m did not differ significantly. The minimum was significantly lower than all values, except that at 0.29 to 0.36 m.

In the Vegetable 2 field, there was an increase in total organic P with depth from 213 g P m^{-3} at the top 0.05 m to a maximum of 254 g P m^{-3} at 0.10 to 0.15 m. Below 0.15 m, there was a decrease with depth to a minimum of 39.7 g P m^{-3} at 0.36 to 0.43 m. Values in the five depths from 0 to 0.29 m were not significantly different, but all of these were significatly greater than those at the two lower depths. The latter did not differ significantly from each other.

Changes in total organic P with field by depths

At the 0 to 0.05 m depth, Pasture 2 had the highest value of total organic P. This was 369 g P m^{-3} and it was significantly greater than values encountered for all other fields except Pasture 1 and Pasture 3. Levels of 338 and 263 g P m^{-3} in the Pasture 1 and Fallow fields, respectively, did not differ significantly from each other. The latter value was not significantly greater than those in the remaining fields.

At 0.05 to 0.10 m, the maximum total organic P was 371 g P m^{-3} and this occurred in Pasture 3. This value was not significantly different from those in Pasture 1, Pasture 2, and the Fallow field at this depth. A level of 262 g P m^{-3} in the Rice field was not significantly less than those determined for Pasture 1 and the Fallow field. In the Virgin, Cane 2, Rice, Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields, values ranged from 197 to 294 g P m^{-3} and did not differ significantly from each other. At this depth, the Cane 1 field had the minimum total organic P, which was 184 g P m^{-3} and was significantly less than those values in the three pastures and the Fallow field.

At the 0.10 to 0.15 m depth, levels of total organic P in Pasture 1, Pasture 2, and the Fallow field were not significantly lower than the maximum of 358 g P m^{-3}, which occurred in Pasture 3. Levels in the former fields were not significantly greater than those in the Cane 1, Cane 2, Rice, Horticulture, Vegetable 1, and Vegetable 2 fields. The Virgin field had 168 g P m^{-3} and this minimum was significantly less than those values in the Pasture 1, Pasture 2, Pasture 3, and Fallow fields at this depth.

At 0.15 to 0.22 m, the Fallow field had the maximum of 350 g P m^{-3} and this was significantly higher than all other values, except those in the Horticulture and Vegetable 1 fields. The latter were not significantly higher than levels found in the Pasture 2, Cane 1, Cane 2, Rice, and Vegetable 2 fields. Of these, only that in the Horticulture field was significantly greater than the value determined for Pasture 3. The level of total organic P in Pasture 1 did not differ significantly from those in the Pasture 2, Pasture 3, Cane 1, Cane 2, and Rice fields at this depth. The minimum of 116 g P m^{-3} occurred in the Virgin soil and was significantly lower than values for the Rice, Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields.

At the 0.22 to 0.29 m depth, the Fallow field had a significantly high level of total organic P, which was 373 g P m^{-3}. Values in the Cane 2, Horticulture, Vegetable 1, and Vegetable 2 fields did not differ significantly from each other. Of the latter, only that in the Horticulture field was significantly greater than levels found in Pasture 2, Cane 1, and Rice fields at this depth. Values of total organic P found in the Pasture 2, Pasture 3, Virgin, Cane 1, Cane 2, Rice, and Vegetable 1 fields did not differ significantly from each other. The minimum of 89.0 g P m^{-3} occurred in Pasture 1 and this was significantly less than estimates of total organic P in the Cane 2 Horticulture, Fallow, Vegetable 1 and Vegetable 2 fields.

At 0.29 to 0.36 m, the maximum level of total organic P was 324 g P m^{-3}. This occurred in the Fallow field and was not significantly higher than the level in the Horticulture field. Both of these values, however, were significantly greater than those in all other fields, which ranged from 50.2 to 133 g P m^{-3} and did not differ significantly from each other.

At the 0.36 to 0.43 m depth, the Fallow field had the maximum, 187 g P m^{-3}, of total organic P. This was not significantly different from the value found for the Horticulture field. Both of these levels were significantly higher than those in all other fields, which ranged from 30.2 to 76.9 g P m^{-3} and were not significantly different from each other.

Residual Organic P

Residual organic P is that organic P which was not extracted by hot 0.1N HCl. Values of residual organic P ranged from 0 to 217 g P m^{-3} in the samples of Pahokee muck studied. The distributions of these data with depth for fields are shown in Fig. 17. Relatively low values of residual organic P were determined in the Horticulture, Vegetable 1, and Vegetable 2 fields, particularly in the depths from 0 to 0.29 m. Analysis of variance indicated that the field x depth interaction for residual organic P was not significant, but that the main effects of field and depth were both very highly significant (Table 8). The statistical model explained 78% of the variation in the data.

Mean residual organic P by fields

The highest mean of residual organic P was 408 g P m^{-3} and it occurred in the Fallow field (Table 12). This value was not significantly higher than those ranging from 310 to 353 g P m^{-3} in the Pasture 2, Pasture 3, Virgin, Cane 1, Cane 2, and Rice fields. Of the latter, only those values in Pasture 2 and the Rice paddy were significantly greater than that found in Pasture 1. Means of residual organic P in the Horticulture, Vegetable 1, and Vegetable 2 fields were 75.7, 84.9,

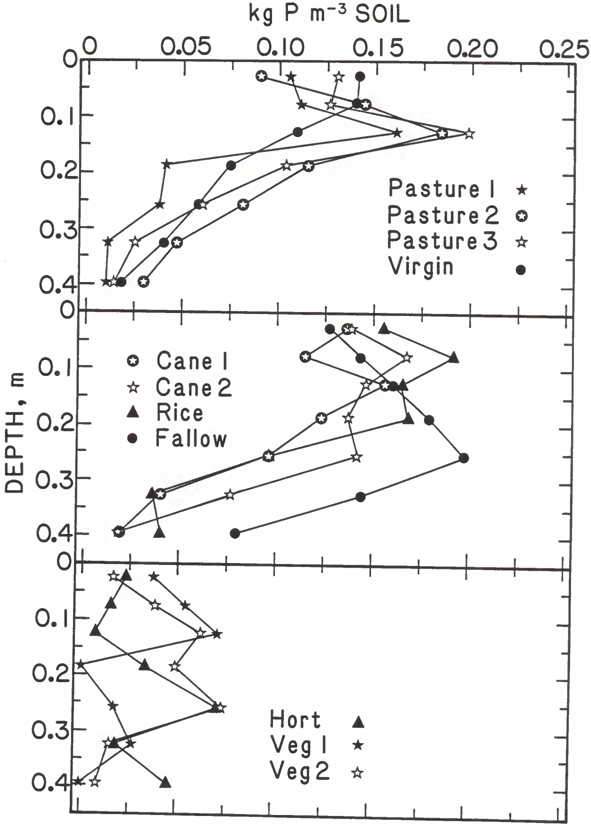


Fig. 17. Residual organic P not extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

Table 12. Main effects of fields and depths on residual organic P not extracted by hot 0.1N HCl from Pahokee muck.

Field	Residual organic P†	Depth	Residual organic P†
	g P m^{-3}	m	g P m^{-3}
Pasture 1	239 b	0 to 0.05	99.8 b
Pasture 2	351 a	0.05 to 0.10	113.0 ab
Pasture 3	341 ab	0.10 to 0.15	129.0 a
Virgin	310 ab	0.15 to 0.22	92.8 b
Cane 1	317 ab	0.22 to 0.29	86.0 b
Cane 2	329 ab	0.29 to 0.36	43.5 c
Rice	353 a	0.36 to 0.43	25.6 c
Fallow	408 a		
Horticulture	75.7 c		
Vegetable 1	84.9 c		
Vegetable 2	102 c		

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

and 102 g P m^{-3}, respectively, and did not differ from each other significantly. However, these values were significantly lower than those for all other fields.

Mean residual organic P by depths

Mean values of residual organic P increased with depth to a maximum of 129 g P m^{-3} at 0.10 to 0.15 m. Below 0.15 m, values decreased with depth to a minimum of 25.6 g P m^{-3} at 0.36 to 0.43 m. The maximum value was significantly higher than levels at all other depths except that at 0.05 to 0.10 m. Means determined at the four depths from 0 to 0.10 m and 0.15 to 0.29 m did not differ significantly from each other. The 0.29 to 0.36 m depth had a mean of 43.5 g P m^{-3}, which was not significantly greater than the minimum value. However, both were significantly less than all means determined for depths above 0.29 m.

Associated determinations on ashed soil

Data for Ca, Mg, K, Al, Fe, and Cu from ashed samples of Pahokee muck are tabulated in Table A-26, A-27, A-28, A-29, and A-31, respectively. The distributions of Mg, K, and Al with depth for fields are shown in Fig. A-5, A-6, and A-7, respectively. A summary of the analysis of variance for Mg, K, Al, and Cu determined by ashing appears in Table A-33.

The distribution of Cu, determined by ashing, with depth for fields, is shown in Fig. 18. Values ranged from 0.70 to 74 g Cu m^{-3} for the samples of soil studied. Analysis of variance indicated that the field x depth interaction for Cu by ashing was very highly significant and that the statistical model explained 93% of the variation in the data

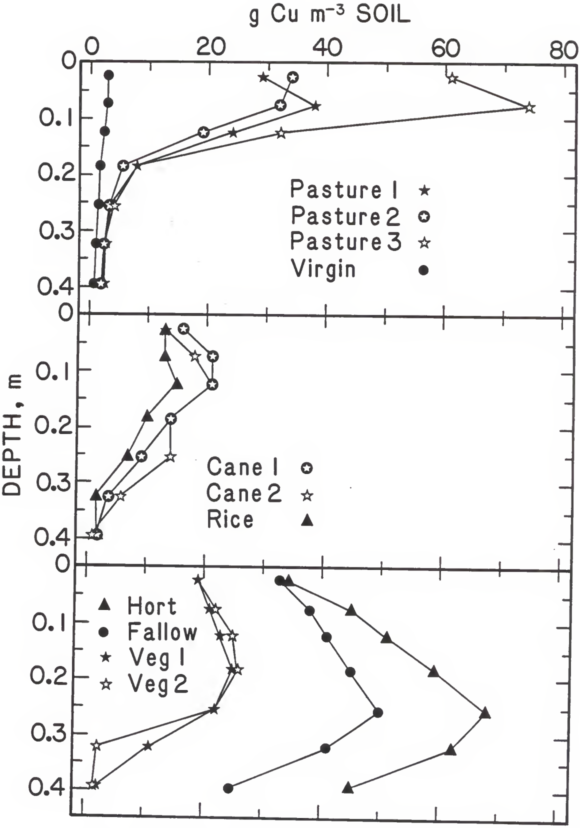


Fig. 18. Copper after ashing of Pahokee muck from 11 fields sampled at seven depths.

(Table A-33). Variability was 37% compared to 74 and 77% encountered with double acid-extractable and hot 0.1N HCl-extractable Cu, respectively.

Very low levels of total Cu occurred throughout the Virgin profile (Fig. 18). Low values were also found below 0.22 m in the three pastures, and at the lowest depth in the Cane 1, Cane 2, Rice, Vegetable 1, and Vegetable 2 fields. Relatively high levels of Cu occurred in the top 0.10 m of the pastures, notably Pasture 3, and throughout the Fallow and Horticulture profiles. Although the relative magnitudes of Cu between fields varied, the depth distributions of Cu generally resembled those of total P for each field (Fig. 15). This was particularly noticeable for the three pastures or the Horticulture and Fallow fields. It is evident from this similarity that the factors affecting the distribution of Cu and total P in the soil studied may be the same. In the pastures, deposition of waste by grazing cattle is the probable cause of increased levels of Cu and total P in the top 0.10 m of soil. The animals grazing on these pastures are fed a mineral mixture containing Cu and P (personal communication, R.J. Allen, AREC, Belle Glade). Since these fields have received very little tillage, Cu and P have not been redistributed to a greater depth by homogenization. In addition, grass growing on these pastures may contribute to the maintenance of high levels of these elements near the soil surface. Repeated applications of Cu, either as fertilizer or in fungicides (Lucas, 1982), are probably the cause of increased Cu levels in the other cultivated fields. In the Horticulture and Fallow fields, the depth distribution of Cu (Fig. 18) closely resembled that of bulk density (Fig. 4) for these fields. This indicates that a relatively constant composition of total Cu occurred with depth in these fields. Comparison of the depth distributions of total P (Fig. 15) for these two fields with corresponding depth distributions of bulk density (Fig. 4) revealed somewhat similar trends. Again, this indicates a relatively constant composition of total P throughout the profiles of the Horticulture and Fallow fields. This is probably the result of homogenization of the soil in these fields through tillage. These results emphasize the importance of the effects of soil management and land use on the distribution of P both with depth and between fields.

Relationships between Categories of Soil P

Values for the various categories of soil P were expressed as percentages of each other for each sample of Pahokee muck studied. Analysis of variance indicated that there were very highly significant field x depth interactions for the ratio of inorganic P extracted by water to that extracted by double acid or by hot 0.1*N* HCl (Table A-34). The statistical model explained 99 and 96% of the variation, respectively. The field x depth interaction for the percent water-extractable inorganic P of total P by ashing was significant at the 5% level, with the model explaining 86% of the variation. Each significant field x depth interaction means that the proportion of inorganic P extracted by water, relative to that extracted by double acid, hot 0.1*N* HCl, or total P by ashing, changed in a different manner with depth between fields or vice versa.

Values for each of these ratios were averaged for the three depths from 0 to 0.15 m for each field and appear in Table 13. In the Virgin field, water extracted more inorganic P than did double acid. The reason

Table 13. Percentages of partitioned P at 0 to 0.15 m depth from fields on Pahokee muck.

	Ratio of P by partition[†], %						
Field	P by W / P by DA	P by W / Total inorg. P	P by W / Total P	P by DA / Total inorg. P	P by DA / Total P	Total Inorg. P / Total P	Org. P by HCl / Total org. P
Pasture 1	9.6	4.0	2.0	43.4	21.9	47.9	62.6
Pasture 2				34.1	17.1	44.7	62.3
Pasture 3				29.6	16.3	47.8	58.7
Virgin	168.0	13.6	3.3	8.5	2.0	24.1	36.5
Cane 1				44.6	15.9	35.4	35.2
Cane 2	11.5	3.7	1.2	32.8	11.0	34.0	32.0
Rice	4.8	2.8	1.5	59.2	31.3	53.0	25.1
Fallow	6.8	3.3	1.0	48.1	15.2	31.6	51.9
Horticulture	7.3	4.1	3.0	56.0	40.2	71.8	107.0
Vegetable 1				57.6	31.1	54.3	75.0
Vegetable 2	7.5	3.7	1.5	50.0	20.8	42.0	83.7

[†] Terms: P by W is inorganic P by water extraction; P by DA is inorganic P by double acid extraction; Total inorg. P is inorganic P by hot 0.1*N* HCl; Total P is after ashing; Org. P by HCl is total P by hot 0.1*N* HCl minus total inorganic P; Total org. P is total P minus total inorganic P.

for this is not clear, but there may have been precipitation of P as Fe or Al phosphates during extraction with double acid. In the other fields, from 4.8 to 11.5% of the double acid-extractable inorganic P was extractable with water. Averaged values for the ratio of inorganic P extracted by water to that extracted by hot 0.1N HCl ranged from 2.8 to 4.1% in the cultivated fields. A high value of 13.6% occurred in the Virgin soil, indicating that proportionally more of the total inorganic P was extracted by water from this soil than from the cultivated soils. Percentages of the total soil P extracted as inorganic P by water ranged from 1 to 3% for the cultivated soils. A slightly higher value of 3.3% was found in the Virgin soil.

Correlations were done between the categories of soil P with values expressed on a soil weight basis for all of the soil samples studied. There was a very highly significant correlation between inorganic P extracted by water and inorganic P extracted by double acid and the r^2 value was 0.75. Similarly, correlations between inorganic P extracted by water and inorganic P extracted by hot 0.1N HCl or total P by ashing were very highly significant with r^2 values of 0.77 and 0.71, respectively.

Analysis of variance revealed that the field x depth interaction was not significant for the ratio of inorganic P extracted by double acid to that extracted by hot 0.1N HCl (Table 14). There was a very highly significant difference between the means for the fields, while the difference between the means by depth was significant at the 5% level. Similarly, the field x depth interaction for the ratio of inorganic P extracted by double acid to total P by ashing was not significant (Table 14). There was a very highly significant difference

Table 14. Analysis of variance for ratios of categories of soil P in Pahokee muck from 11 fields sampled at seven depths.

Model fit†			Factors‡		
r^2	∝	CV	Fields (F)	Depths (D)	FxD
Inorganic P by double acid / Inorganic P by hot 0.1N HCl					
0.73	***	27	***	*	NS
Inorganic P by double acid / Total P					
0.85	***	34	***	**	NS
Organic P by hot 0.1N HCl / Total P by hot 0.1N HCl					
0.82	***	19	***	***	NS
Organic P by hot 0.1N HCl / Total organic P					
0.80	***	32	***	NS	NS
Inorganic P by hot 0.1N HCl / Total P					
0.80	***	25	***	**	NS
Total P by hot 0.1N HCl / Total P					
0.82	***	16	***	*	NS
Residual organic P / Total organic P					
0.83	***	32	***	*	NS
Residual organic P / Total P					
0.81	***	38	***	*	NS
Total organic P / Total P					
0.80	***	17	***	**	NS

† r^2, ∝, and CV are coefficient of determination, level of significance, and coefficient of variation, respectively.

‡ NA, NS, *, **, and *** are not applicable, not significant, and significant at the 5, 1, and 0.1% levels, respectively.

between the means for fields and a highly significant difference between the means for depths. Values for both of these ratios were averaged for the three depths form 0 to 0.15 m (Table 13). For the ratio of inorganic P by double acid to inorganic P by hot 0.1N HCl in the cultivated fields, values ranged from 29.6 to 59.2%. The Virgin field had a much lower value of 8.5%, which resulted from the low values of inorganic P extracted by double acid. The correlation of inorganic P extracted by these two reagents from all of the soil samples studied was very highly significant with a r^2 value of 0.93. Means for the ratio of inorganic P extracted by double acid to total P ranged from 11.0 to 40.2% (Table 13). Only 2% of the total P in these depths of the Virgin soil was extractable as inorganic P by double acid. The correlation between inorganic P extracted by double acid and total P by ashing was very highly significant and the r^2 value was 0.79.

The field x depth interaction was not significant for the proportion extracted as inorganic P by hot 0.1N HCl compared to total P (Table 14). There were very highly significant differences both between the means for field and between means by depth. Means for the ratio of total inorganic P extracted by hot 0.1N HCl to total P for soil from 0 to 0.15 m of the cultivated fields ranged from 31.6 to 71.8% (Table 13). That of the Virgin soil was 24.1%, which indicates that 75.9% of the total P in this soil occurred as organic P. The correlation between inorganic P extracted by hot 0.1N HCl and total P by ashing for all soil samples was very highly significant with a r^2 value of 0.91.

The field x depth interaction for the percent organic P extracted by hot 0.1N HCl of the total organic P was not significant. There was a very highly significant difference between the means for fields. There was no significant difference, however, between the means for depths. The range of values for percent organic P extracted of the total organic P for the cultivated fields was 25.1 to 107% (Table 13). The latter value occurred in the Horticulture field and is greater than 100% because hot 0.1N HCl extracted slightly more total P than was determined by ashing in some of the depths of both cores from this field. This overestimate may have resulted from sample variability, volatile loss of P during ignition, or incomplete solubilization of P compounds during the extraction of the ashed samples. In the Virgin field, 36.5% of the total organic P was extracted with hot 0.1N HCl. The correlation between organic P extracted and total organic P for all of the soil samples studied was very highly significant, but the r^2 value was only 0.48.

It is interesting to note that inorganic P and Cu extracted by double acid were highly correlated and the r^2 value was 0.41. Similarly, the r^2 value was 0.48 for the highly significant correlation of inorganic P and Cu extracted by hot 0.1N HCl. Total P and Cu after ashing were also highly correlated and the r^2 value was 0.72. The above correlations of P and Cu were much better than corresponding ones with Ca, Fe, and Al, which were rarely significant. This reflects the common addition of P and Cu to fields of Pahokee muck.

Aerobic Incubation Experiments

In order to investigate the behavior of P in Pahokee muck, a series of laboratory experiments was conducted. The first of these was aerobic incubation of samples from the top 0.15 m of the Vegetable 2 and Virgin fields.

Evolution of Carbon Dioxide during Soil Incubation

After 47 days of incubation, the vegetable soil with KH_2PO_4 added at rates of 0, 20, 40, and 80 mg P kg^{-1} produced 0.870, 0.873, 1.00, and 0.800 g of carbon as carbon dioxide (CO_2-C) kg^{-1} of soil, respectively. Corresponding values for the virgin soil were 1.06, 1.03, 0.916, and 0.920 g CO_2-C kg^{-1}. The mean amounts of CO_2-C evolved during the incubation period by the vegetable and virgin soils were 0.886 and 0.982 g kg^{-1} of soil, respectively. These values agree well with those determined for samples of Pahokee muck by Terry (1980). The addition of corn stover at the rate of 22.4 Mg ha^{-1} greatly increased the evolution of CO_2-C from both soils at all rates of added P. The vegetable soil with stover produced 5.31, 5.41, 5.50, and 5.23 g CO_2-C kg^{-1}, where P was added at 0, 20, 40, and 80 mg P kg^{-1}, respectively. Corresponding evolutions from the virgin soil with corn stover were 4.92, 4.84, 4.67, and 4.49 g CO_2-C kg^{-1}. Means were 5.36 and 4.73 g CO_2-C kg^{-1} of vegetable and virgin soil, respectively.

The cumulative CO_2-C production with time for the vegetable and virgin soils with 40 mg of added P kg^{-1}, with or without added corn stover, appears in Fig. 19. Trends in cumulative CO_2-C with time were very similar at the other levels of added P for each of the soils with or without added corn stover.

Analysis of variance was carried out for the daily rates of CO_2-C production (Table 15). This was done separately for the soils with or without added corn stover. For soil without corn stover added, the statistical model explained 96% of the variation in the data. The soil x sampling time x P-rate interaction was not significant, nor were the sampling time x P-rate and soil x P-rate interactions. However, there

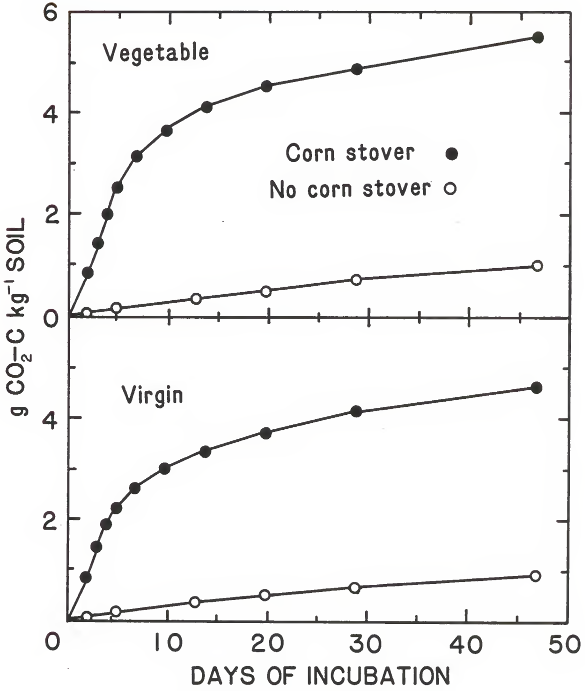


Fig. 19. Cumulative carbon dioxide production with time from soil from two fields of Pahokee muck incubated with 40 mg added P per kg with and without corn stover.

Table 15. Analysis of variance for the rate of carbon dioxide production from Pahokee muck from two fields incubated without corn stover at four rates of added P.

Factor†	Soil without stover	Soil with stover
r^2	0.96	1.00
∝	***	***
CV	11	5
Soil (S)	NA	NA
Sampling time (T)	NA	NA
P rate (PR)	**	NA
S x T	***	NA
S x PR	NS	NA
T x PR	NS	NA
S x T x PR	NS	*

† r^2, ∝, CV, NA, NS, *, **, and *** are coefficient of determination, level of significance, coefficient of variation, not applicable, not significant, and significant at the 5, 1, and 0.1% levels, respectively.

was a very highly significant difference between the daily CO_2-C production rates when averaged over both soils and all sampling periods for levels of added P. Analysis of this difference (Table 16) showed that the mean daily CO_2-C production rate at 80 mg of added P kg^{-1} of soil was 23.6 mg CO_2-C kg^{-1} of soil day^{-1}, which was significantly less than rates of 26.8, 26.4, and 25.6 mg CO_2-C kg^{-1} day^{-1} for 0, 20, and 40 mg of added P kg^{-1}, respectively. The reason for the decreased production rate of CO_2-C at the highest level of added P is not clear. The results did not show a significant decrease in CO_2-C evolution in response to increasing level of added P in the range of 0 to 40 mg P kg^{-1} of soil.

The soil x sampling time interaction for the daily rate of CO_2-C production from soil without stover was significant at the 0.1% level (Table 15). Further analysis was conducted centering on the difference between means of daily CO_2-C production, averaged over rates of added P, between the two soils at each sampling time and between sampling times for each soil.

For the vegetable soil, the rate of CO_2-C production decreased from 47.5 mg CO_2-C kg^{-1} of soil day^{-1}, for the first two days of incubation, to 12.1 mg CO_2-C kg^{-1} of soil day^{-1}, for the last 18 days (Table 17). The former was significantly higher than all others determined for this soil. The rate of CO_2-C production was 29.5 mg CO_2-C kg^{-1} of soil day^{-1} from the second to the fifth day, and this was significantly higher than rates measured during the remainder of the incubation. Between 13 and 29 days after initiation of the incubation, the three rates measured were not significantly different and ranged from 20.6 to 21.0 mg CO_2-C kg^{-1} of soil day^{-1}. A rate of 12.1 mg CO_2-C kg^{-1} day^{-1}, measured for the

Table 16. Analysis of significant differences between the mean rate of carbon dioxide production from Pahokee muck from two fields incubated without corn stover at four rates of added P.

Sampling time	Added P, mg kg^{-1}			
	0	20	40	80
days	mg CO_2-C kg^{-1} day^{-1}			
2	47.7	49.3	42.2	41.6
5	30.5	27.8	28.9	24.5
13	22.8	22.2	23.1	23.0
20	21.8	23.6	22.4	22.0
29	25.4	22.6	22.7	19.1
47	12.6	13.1	14.2	11.4
Mean†	26.8 a	26.4 a	25.6 a	23.6 b

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

Table 17. Analysis of the significant soil x sampling time interaction on the rate of carbon dioxide production from Pahokee muck from two fields incubated without corn stover at four rates of added P.

	Sampling time, days					
Factor†	2	5	13	20	29	47
			Vegetable soil			
Mean, mg CO_2-C kg^{-1} day^{-1}	47.5	29.5	20.6	20.6	21.0	12.1
DMRT, sampling times	a	b	c	c	c	d
DMRT, soils	a	a	b	b	b	b
			Virgin soil			
Mean, mg CO_2-C kg^{-1} day^{-1}	42.9	26.4	25.0	24.3	23.9	13.6
DMRT, sampling times	a	b	b	b	b	c
DMRT, soils	b	a	a	a	a	a

† Horizontal means (sampling times) and vertical means (soils) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

last 18 days of incubation, was significantly lower than all other rates of CO_2-C production measured for this soil.

For the virgin soil, the rate of CO_2-C production also decreased with time during the course of the incubation (Table 17). The initial rate of 42.9 mg CO_2-C kg^{-1} of soil day^{-1}, measured for the first two days, was significantly higher than all other rates determined for this soil. Between 2 and 29 days after time zero, CO_2-C production rates decreased from 26.4 to 23.9 mg CO_2-C kg^{-1} of soil day^{-1}. The four rates measured in this time interval were not significantly different. The CO_2-C production rate for the last 18 days of incubation was 13.6 mg CO_2-C kg^{-1} of soil day^{-1} and this rate was significantly lower than all other rates measured for the virgin soil.

During the first two days of incubation, the vegetable soil had a significantly higher CO_2-C production rate than did the virgin soil (Table 17). Between the second and fifth day of incubation, rates of CO_2-C production from the two soils did not differ significantly. However, after the fifth day, the rates of CO_2-C production for the virgin soil were significantly higher than those for the vegetable soil.

The high initial rates of CO_2-C production encountered with both soils reflect a flush in microbial activity. This was probably induced by the rewetting and mixing of soil during the preparation of samples for incubation. After this flush, rates of CO_2-C production from both soils declined and tended to stabilize as the microbial populations declined and became adjusted to prevailing conditions in the incubating soil. Lower rates of CO_2-C production from both soil after 29 days of incubation indicate that some factor in the soil, probably water-soluble carbon, was limiting the microbial populations. The fact that the rate of CO_2-C production from the vegetable soil was initially greater, but then less than that of the virgin soil after 5 days of incubation, may have resulted from the presence of different microbial communities in these soils.

Analysis of variance for the soils with added stover (Table 15) indicated that the soil x sampling time x P-rate interaction for daily CO_2-C production rates was significant at the 5% level. The statistical model explained 100% of the variation in the data. A significant three-factor interaction means that the effect of any two-factor interaction changes over the levels of the third factor. Further statistical analysis of the nature of each of the three two-factor interactions, at the levels of the third factor, was carried out. A graphical presentation of the data appears in Fig. 20, where measured rates of CO_2-C production have been plotted at the midpoints of the interval between sampling times.

For the vegetable soil incubated with corn stover, there was a highly significant sampling time x P-rate interaction on the rate of CO_2-C production (Table 18). Further analysis of the differences between rates of CO_2-C production, between rates of added P at each sampling period, and between sampling periods at each rate of added P was conducted (Table A-36). There were significant differences between rates of CO_2-C production at the four rates of added P for the first seven days of incubation. For the first two days of incubation, vegetable soil plus corn stover and 40 mg P kg^{-1} of soil had a rate of 451 mg CO_2-C kg^{-1} day^{-1}, which was significantly higher than those ranging from 395 to 410 mg CO_2-C kg^{-1} day^{-1} for treatments at the other three rates of added P. Between 2 and 3 days of incubation, vegetable

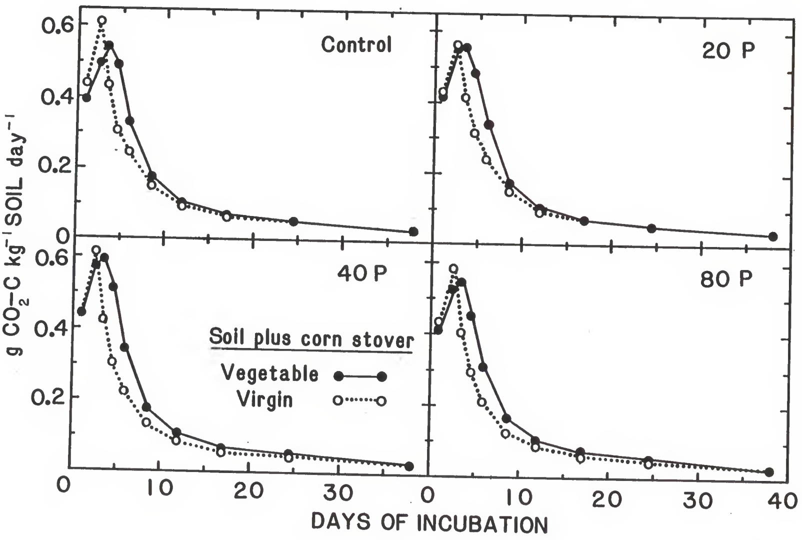


Fig. 20. Rate of carbon dioxide production from Pahokee muck from two fields incubated with corn stover at four rates of added P (P is mg of added P kg^{-1} of soil).

Table 18. Analysis of variance for the sampling time x P-rate interaction on the rate of carbon dioxide production at levels of soil for samples of Pahokee muck incubated with corn stover at four rates of added P.

	Factor†		
Soil	Sampling time (T)	P rate (PR)	T x PR
Vegetable	NA	NA	**
Virgin	**	**	NS

† NA, NS, and ** are not applicable, not significant, and significant at the 1% level, respectively.

soil plus stover and 40 mg P kg^{-1} had the maximum rate of 573 mg CO_2-C kg^{-1} day^{-1}, which was not significantly higher than a rate of 555 mg CO_2-C kg^{-1} day^{-1} for soil plus stover and 20 mg P kg^{-1}. The latter was not significantly higher than a production rate of 537 mg CO_2-C kg^{-1} of soil day^{-1} at an added P rate of 80 mg P kg^{-1}. The evolution rate for the control treatment was 496 mg CO_2-C kg^{-1} of soil day^{-1}, which was significantly less than the other CO_2-C production rates measured in this time interval.

From the third to fourth day of incubation, the soil and stover treatment with 40 mg P kg^{-1} of soil had a significantly high CO_2-C production rate of 593 mg CO_2-C kg^{-1} of soil day^{-1}. Evolution rates for vegetable soil with stover at the three other levels of added P did not differ significantly from each other. Between the fourth and fifth days of incubation, vegetable soil plus corn stover and 40 mg P kg^{-1} had the maximum CO_2-C production rate, which was 512 CO_2-C kg^{-1} of soil day^{-1}. This was not significantly higher than evolution rates determined for treatments with 0 or 20 mg of added P kg^{-1} of soil, but the rate of CO_2-C production for that with 80 mg of added P kg^{-1} was significantly lower. Between 5 and 7 days of incubation, production rates of 331, 342, and 343 mg CO_2-C kg^{-1} of soil day^{-1} were determined for the vegetable soil plus stover and 0, 20, and 40 mg P kg^{-1}, respectively. The CO_2-C evolution rate for the control treatment was not significantly greater than the rate of 310 mg CO_2-C kg^{-1} of soil day^{-1} determined for vegetable soil receiving stover and 80 mg added P kg^{-1}. For samplings after the seventh day of incubation, there was no significant effect of the rate of added P on the rate of CO_2-C production from the vegetable soil plus corn stover.

From the above analysis, it is evident that there was no definite effect of the rate of added P on the rate of CO_2-C production from the vegetable soil plus stover throughout the incubation. Although the CO_2-C evolution rates for the treatment with 40 mg of added P kg^{-1} of soil were consistently higher for the four samplings during the first 10 days of incubation, this was significant only at the first and third sampling times. Also, the rates of CO_2-C production from treatments which had received added P were significantly greater than that of the control only during the time interval between the second and third days of incubation.

The maximum rate of production of CO_2-C from the control treatment of vegetable soil plus corn stover was 543 mg CO_2-C kg^{-1} of soil day^{-1}, which occurred between the third and fourth days of incubation (Fig. 20). This was significantly higher than all other production rates measured for this treatment throughout the incubation (Table A-36). Rates of 395 and 496 mg CO_2-C kg^{-1} of soil day^{-1} were determined for the time intervals from 0 to 2 days and from 2 to 3 days of incubation, respectively. These rates were significantly different from each other. After the fourth day of incubation, the rate of CO_2-C production decreased with time from the maximum of 543 mg CO_2-C kg^{-1} of soil day^{-1} to a minimum of 31 mg CO_2-C kg^{-1} day^{-1} during the last 18 days of incubation (Fig. 20). All of the evolution rates determined between these extremes were significantly different from each other, except the two determined between 14 and 29 days of incubation.

The maximum rate of CO_2-C evolution for vegetable soil to which corn stover and 20 mg P kg^{-1} of soil were added was 558 mg CO_2-C kg $^{-1}$ of soil day^{-1} and this also occurred between the third and fourth days of incubation. A similar production rate of 555 mg CO_2-C kg^{-1} of soil day^{-1} was measured between the second and third days of incubation and this was not significantly different from the maximum rate. However, both were significantly higher than the evolution rate of 419 mg CO_2-C kg^{-1} of soil day^{-1}, which occurred during the first 2 days of incubation. Also, both of the former values were significantly higher than all remaining rates of CO_2-C evolution determined during the incubation with this treatment. The latter decreased with time to a minimum of 29 mg CO_2-C kg^{-1} of soil day^{-1}, measured during the last 18 days of incubation (Fig. 20), and all but the two rates determined between 14 and 29 days of incubation differed significantly (Table A-36). The change with time in the rate of CO_2-C evolution from vegetable soil with corn stover and either 40 or 80 mg of added P kg^{-1} of soil was very similar to that already described for the treatment which had received 20 mg P kg^{-1} of soil (Fig. 20, Table A-36). Although the maximum rate of CO_2-C production from all treatments occurred between the fourth and fifth days of incubation, the initial increase with time in the production rate from the control, which had not received added P, was less than that for the other treatments. This may have resulted from a relatively early depletion of readily available P in the vegetable soil. A rapid increase in the microbial population was due to available carbon of the corn stover. However, this possible P limitation was temporary and was not great enough to restrict a further increase in the rate of CO_2-C production between the third and fourth days of incubation.

For the virgin soil incubated with corn stover, the sampling time x P-rate interaction on the rate of CO_2-C production was not significant (Table 18). However, the main effects of sampling time and rate of added P were both significant at the 1% level. Further analysis of the differences between the means of the CO_2-C production rate at the various sampling times or at the four rates of added P was conducted (Table 19). The maximum mean production rate of 593 mg CO_2-C kg^{-1} of soil day^{-1} occurred between the second and third days of incubation. This was significantly greater than all other rates measured during the incubation. After the third day, the rate of CO_2-C production decreased with time to a minimum of 30 mg CO_2-C kg^{-1} of soil day^{-1}, determined for the last 18 days of incubation. All of these rates, except the two between 14 and 29 days of incubation, differed significantly from each other.

From Fig. 20, it can be seen that, at all rates of added P, the maximum rate of CO_2-C production occurred a day earlier for the virgin soil plus stover than for the vegetable soil plus stover. This may have resulted from different microbial populations in the two soils. Conditions may also have been more conducive to microbial growth in the virgin soil after the addition of corn stover.

The rates of CO_2-C production from the virgin soil with corn stover, averaged over the entire incubation, for each rate of added P are summarized in Table 19. The maximum rate was 243 mg CO_2-C kg^{-1} of soil day^{-1} and this was found for the control treatment. This rate was not significantly different from those determined for the treatments to which 20 or 40 mg P kg^{-1} of soil had been added, but all were significantly higher than the minimum rate from the treatment which had

Table 19. Main effects of sampling time and P rate on the rate of carbon dioxide production from virgin soil incubated with corn stover at four rates of added P.

Sampling time	CO_2-C†	P rate	CO_2-C†
days	mg kg^{-1} day^{-1}	mg P kg^{-1}	mg kg^{-1} day^{-1}
2	436 b	0	243 a
3	593 a	20	236 a
4	418 c	40	237 a
5	304 d	80	226 b
7	229 e		
10	139 f		
14	90 g		
20	64 h		
29	53 h		
47	30 i		

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

received 80 mg of added P kg^{-1}. This decreased rate of production of CO_2-C at the highest rate of added P was similar to that observed for the effect of added P on the CO_2-C production rate from either the vegetable or virgin soil without added corn stover. The reason for the negative effect of added P is not evident.

For the treatments with corn stover at each rate of added P, the soil x sampling time interaction on the rate of CO_2-C production was significant at the 1% level (Table 20). Further analysis of the differences in the rates of CO_2-C production between the two soils at each rate of added P for each sampling time was performed (Table A-37). These differences can be seen in Fig. 20. After 2 days of incubation, the rate of CO_2-C production form the vegetable soil plus corn stover without added P was significantly lower than that from the virgin soil with the same treatment. At each of the remaining levels of added P for this time, there was no significant difference in the CO_2-C production rates between soils.

After 3 days of incubation, significant differences between rates of CO_2-C production from the two soils were found at 0, 40, and 80 mg of added P kg^{-1} of soil. In each case, that from the virgin soil with stover was greater than that from the vegetable soil with stover. However, after 4 days of incubation, the situation was reversed, since significantly higher rates of CO_2-C evolution from the vegetable soil with corn stover were found at all rates of added P. This also occurred after 5 or 7 days of incubation. Between the seventh and tenth day of incubation, the difference between rates of CO_2-C production for the treatments at 20 mg of added P kg^{-1} of soil became non-significant, although that from the vegetable soil was still greater. For the other

Table 20. Analysis of variance for the soil x sampling time interaction on the rate of carbon dioxide production at levels of P-rate for samples of Pahokee muck incubated with corn stover.

	Factor†		
P-rate, mg P kg^{-1}	Soil (S)	Sampling time (T)	S x T
0	NA	NA	**
20	NA	NA	**
40	NA	NA	**
80	NA	NA	**

† NA and ** are not applicable and significant at the 1% level, respectively.

levels of added P, significantly more CO_2-C was produced during this time interval by the vegetable soil with corn stover than by the virgin soil with corn stover. Between 10 and 14 days of incubation, the rates of CO_2-C production by both soils with added stover were not significantly different at each level of added P, even though those from the vegetable soil were slightly greater. This was also the case for the three remaining sampling times. It is interesting that, during the last 27 days of incubation, the CO_2-C production rates of all treatments were very similar at each sampling period, although significant differences were found at earlier sampling times. These results indicated that the factors affecting the rate of production of CO_2-C exerted their influence on the microbial population within the first 5 days of incubation (Fig. 20).

It is interesting to note that, during the last 18 days of the incubation, the average rate of CO_2-C production from the treatments with added corn stover was about 30 mg CO_2-C kg^{-1} of soil day^{-1} (Table A-37), compared to an average production rate of about 13 mg CO_2-C kg^{-1} day^{-1} for treatments without corn stover (Table 16). This indicates that, even after 29 days, microbial activity was still being promoted by the added corn stover.

At the end of the incubation of soil for the measurement of CO_2-C evolution, all samples were extracted with water. In general, there was very close agreement between the amounts of water-extractable inorganic P in these samples, after 47 days of incubation, and those determined for corresponding treatments, which were incubated for 48 days in the following experiment (Fig. 21, 22, and 24 in the subsequent section).

Changes in Water-Extractable Inorganic P during Soil Incubation

The changes with time in the water-extractable inorganic P from the vegetable soil incubated with four rates of added P are shown in Fig. 21. For the control, there was a slight decrease in water-extractable inorganic P during the first 5 days, after which time, levels tended to stabilize at about 40 mg P kg^{-1} of soil. With 80 mg of added P kg^{-1} of soil, amounts of water-extractable inorganic P decreased rapidly with time during the first 3 days of incubation. In fact, about 25% of the P added was not recovered by extraction with water immediately after addition to this soil. After 3 days of incubation, water-extractable inorganic P had decreased from 99 to 68 mg P kg^{-1} of soil. Between 3 and 48 days of incubation, levels of inorganic P continued to decline, but at a decreasing rate. After 48 days, 53 mg P kg^{-1} of soil were extracted by water from the samples of vegetable soil which had received 80 mg P kg^{-1}. This amounted to 16% recovery of the added P after 48 days of incubation. Similar trends were found in the data from the treatments to which 20 or 40 mg P kg^{-1} of soil were added (Fig. 21). However, at these lower rates of P addition, water-extractable inorganic P tended to stabilize during the latter stages of incubation. For the 40 mg P kg^{-1} rate of addition, water-extractable inorganic P decreased from 50 mg P kg^{-1} of soil at 15 days to 47 mg P kg^{-1} at 48 days. At the 20 mg P kg^{-1} rate, corresponding water-extractable levels were 45 and 43 mg P kg^{-1} of soil for the respective days. Recoveries of added P were 15 and 18% for 20 and 40 mg of added P kg^{-1} of soil, respectively, after 48 days of incubation.

It is evident from these data (Fig. 21) that some mechanism in the soil is rendering the added P less extractable with water during

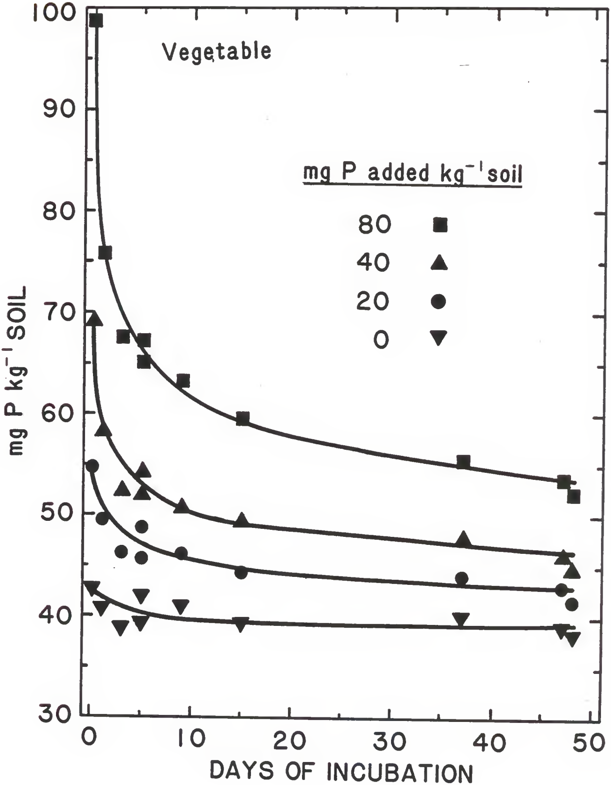


Fig. 21. Change in water-extractable P with time from Pahokee muck from a vegetable field incubated at four rates of added P.

the course of the incubation. This mechanism may be physical adsorption, chemical precipitation, or microbial immobilization of the added P. Results from the previous study of the effect of added P on the rate of CO_2-C evolution from this soil suggest a relatively small contribution by the latter. Although water-extractable Ca and Mg were determined, there was little difference in their amounts either between rates of added P at each sampling time, or between sampling times for each rate of added P. This may have resulted, in part, from the large amounts of these cations, relative to that of inorganic P, extracted by water from this soil. Large decreases in water-extractable inorganic P would correspond to proportionally small decreases in water-extractable Ca or Mg, which may not have been detectable with the procedure used.

The changes with time in water-extractable inorganic P during the incubation of vegetable soil, which had received corn stover and four rates of added P, appear in Fig. 22. The corn stover itself contained an amount of water-extractable inorganic P equivalent to 25.3 mg P kg^{-1} of soil. Consequently, the initial amounts of water-extractable inorganic P determined for the vegetable soil with stover at each rate of added P were higher than the corresponding determinations for the vegetable soil without corn stover (Fig. 21). Comparison of Fig. 22 with Fig. 21 reveals that the addition or corn stover to the vegetable soil greatly affected the change with time in the water-extractable inorganic P at all rates of added P. Active microbial growth, stimulated by the addition of the corn stover, resulted in an increased initial depletion of water-extractable inorganic P. At the highest rate of P addition, the level of extractable inorganic P decreased from an initial level of 119 mg P kg^{-1} of soil, to 60 mg P kg^{-1} after 5 days

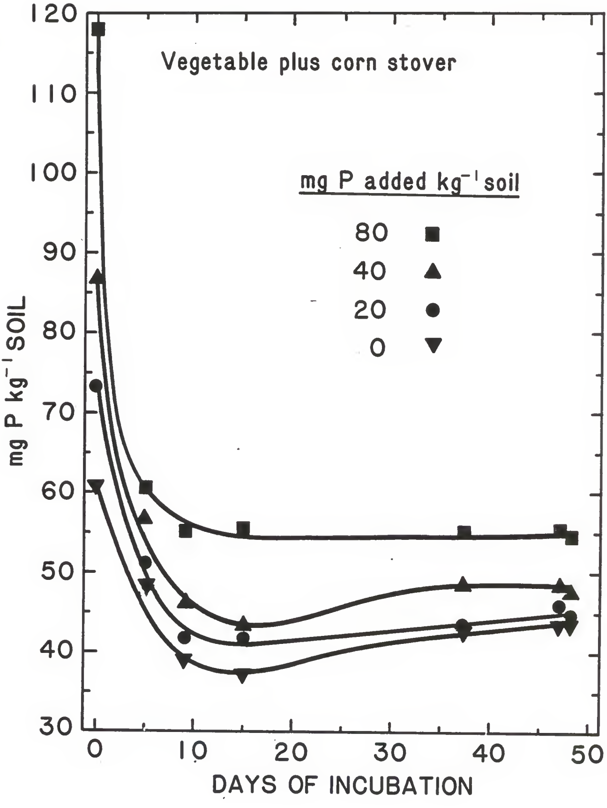


Fig. 22. Change in water-extractable P with time from Pahokee muck from a vegetable field incubated with corn stover at four rates of added P.

of incubation (Fig. 22). Between 9 and 48 days, values stabilized at 55 mg P kg^{-1} of soil. For the addition rates of 0, 20, and 40 mg P kg^{-1} of soil, amounts of water-extractable inorganic P decreased to 37, 42, and 44 mg P kg^{-1} of soil, respectively, at 15 days of incubation. Between 15 and 48 days, levels of extractable inorganic P increased slowly with time to corresponding amounts of 44, 45, and 48 mg P kg^{-1} of soil (Fig. 22).

The changes with time in water-extractable inorganic P from samples of the virgin soil incubated at four rates of added P are shown in Fig. 23. Trends in these data are very similar to those of the vegetable soil treated in the same manner (Fig. 21). For the control treatment of the virgin soil, levels of water-extractable inorganic P were slightly variable throughout the incubation and ranged from 25 to 30 mg P kg^{-1} of soil (Fig. 23). With the P addition of 80 mg P kg^{-1} of soil, levels of water-extractable inorganic P rapidly decreased from an initial estimate of 95 mg P kg^{-1} of soil, to 65 mg P kg^{-1} of soil after 5 days of incubation. After 48 days, 53 mg P kg^{-1} of soil were extractable with water and amounted to a 29% recovery of the added P. However, there was little indication from these data that the level of water-extractable inorganic P, at this rate of P addition, had stabilized at this time. Similar trends were observed in the data from virgin soil to which 20 or 40 mg P kg^{-1} of soil had been added (Fig. 23). However, values of water-extractable inorganic P from the former above rate, tended to level off between 15 and 48 days of incubation. At 48 days, amounts of water-extractable inorganic P extracted from soil which had received 20 or 40 mg P kg^{-1} were 35 and 38 mg P kg^{-1} of soil, respectively. These values corresponded to 30 and 22% recovery of added P.

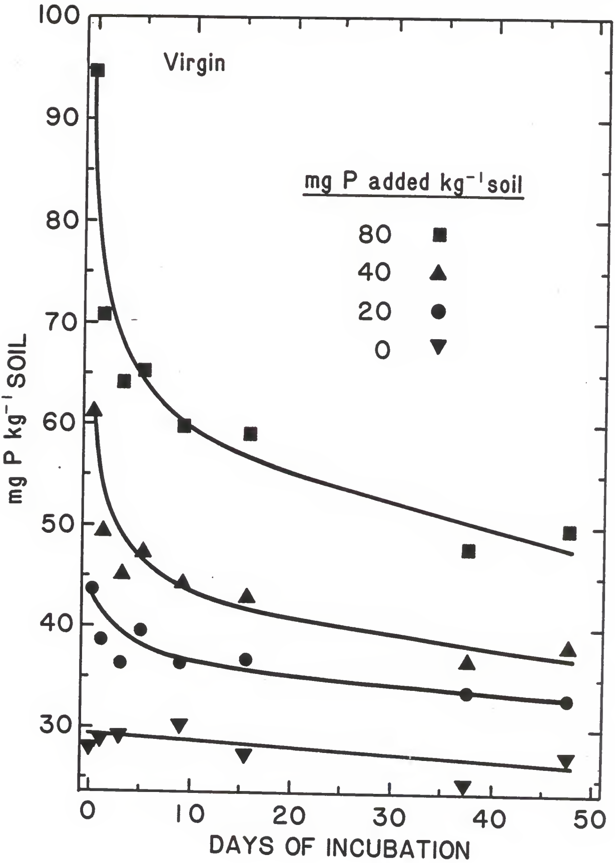


Fig. 23. Change in water-extractable P with time from Pahokee muck from a virgin field incubated at four rates of added P.

The changes with time in water-extractable inorganic P from virgin soil with corn stover at four rates of added P are shown in Fig. 24. Comparison with the corresponding data for this soil incubated in the absence of corn stover (Fig. 23) shows that, within the first 3 days of incubation, the stover caused a large change in the rate of depletion of water-extractable inorganic P. Low levels of water-extractable inorganic P occurred on the fifth day of incubation, which was much sooner than with the vegetable soil plus corn stover (Fig. 22). For the virgin soil plus stover these low levels were 13, 17, 23, and 33 mg P kg^{-1} of soil for the P addition rates of 0, 20, 40, and 80 mg P kg^{-1} of soil, respectively. From 5 to 48 days of incubation, levels of water-extractable inorganic P increased steadily with time (Fig. 24). At 48 days, amounts of inorganic P extracted were 23, 26, 29, and 36 mg P kg^{-1} of soil for rates of 0, 20, 40, and 80 mg of added P kg^{-1} of soil, respectively.

The replenishment of the water-extractable inorganic P fraction was found for both sets of treatments to which corn stover was added. Several processes may have contributed to this increase in water-extractable inorganic P. These include the release of inorganic P upon lysis of microbial cells during the population decline, also indicated by the decrease in CO_2-C production rates (Fig. 20); mineralization of organic P in either the soil itself or in the added corn stover; solubilization of slightly soluble inorganic phosphates either through the action of microorganisms or in response to a displaced equilibrium between soluble and slightly soluble fractions; or desorption of inorganic P in response to a displaced equilibrium between inorganic P in the solution and sorbed phases. All of these

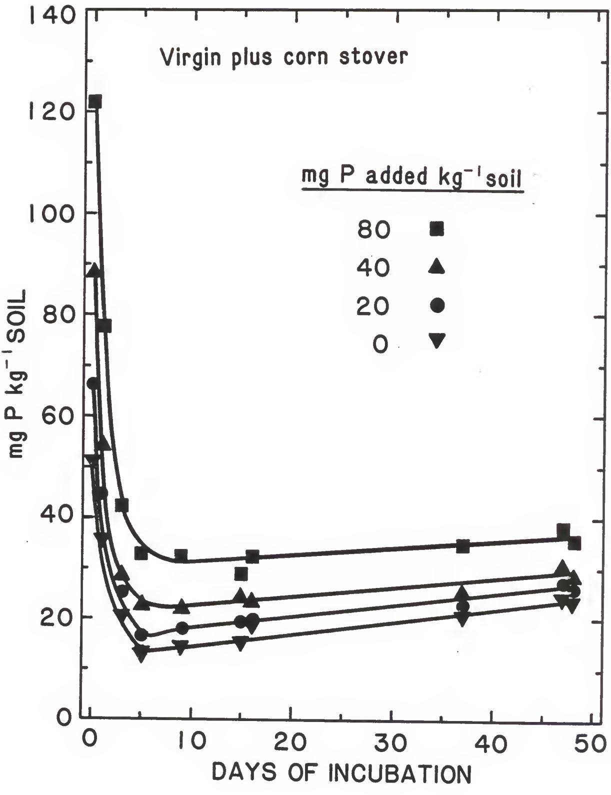


Fig. 24. Change in water-extractable P with time from Pahokee muck from a virgin field incubated with corn stover at four rates of added P.

processes may have occurred simulataneously throughout the entire incubation period. The replenishment of inorganic P in samples of Pahokee muck was further investigated in the next experiment.

Replenishment of P after Leaching

Changes with time in inorganic P leached with water from soil samples, which had previously been extracted with water, are shown in Fig. 25. Total P amounts determined by ashing, for these surface (0 to 0.15 m) soils from the Vegetable 2, Rice, and Fallow fields were 2.04, 1.20, and 1.19 g P kg^{-1} of soil, respectively. Corresponding amounts of water-extractable inorganic P from the vegetable, rice, and fallow soils were 36.3, 19.1, and 13.2 mg P kg^{-1} of soil, respectively. Data in Fig. 25 shows that the inorganic P fraction was replenished after the initial water extraction and after each of three leaching events. Although amounts of inorganic P differed between soil at each time of leaching, relatively constant amounts were determined with time for each soil. The pattern of inorganic P leached was the same at each time, so that, in the order of decreasing amounts of inorganic P leached, the sequence of soil was always vegetable > rice > fallow. This sequence was also repeated for the values of total P and water-extractable inorganic P. This suggests that, for the soils studied, the larger the amount of total P in the soil, the higher the amounts of P maintained as water-extractable or water-leachable inorganic P.

The changes with time in nitrate-N leached from these soil samples appear in Fig. 26. Values from the initial water extraction were 760, 1000, and 680 mg nitrate-N kg^{-1} of soil for the vegetable, rice, and

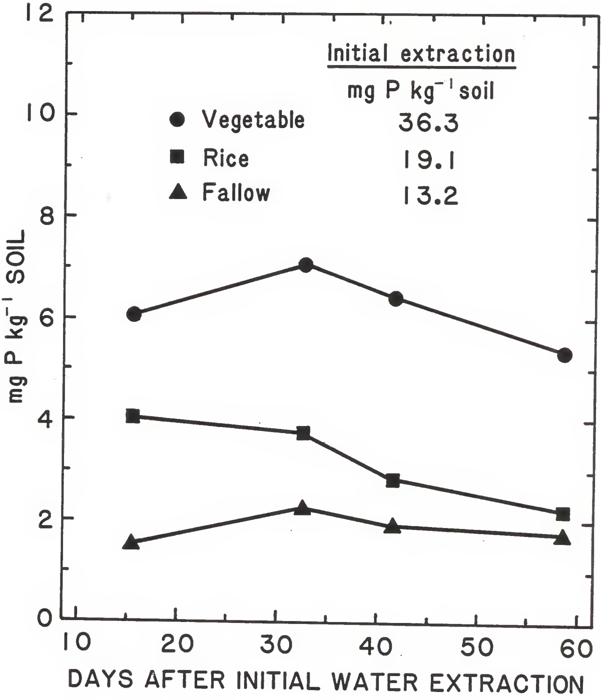


Fig. 25. Change with time in inorganic P leached with water from Pahokee muck from three fields.

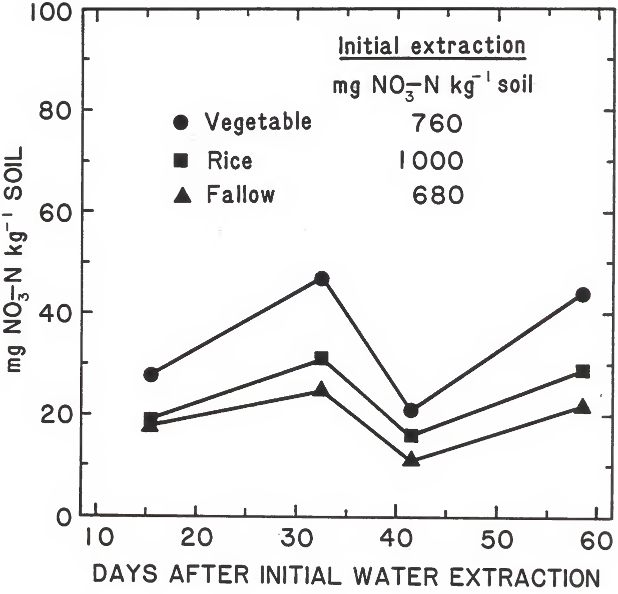


Fig. 26. Change with time in nitrate-N leached with water from Pahokee muck from three fields.

fallow soils, respectively. The data in Fig. 26 show that, compared to initial nitrate-N values, relatively low levels of nitrate-N were regenerated by all soils after the initial water extraction.

At each leaching event, the nitrate regeneration was in the same soil sequence as found for water-soluble inorganic P. The decrease in nitrate in all three soils at 42.5 days was not observed for the corresponding water-soluble inorganic P values. The nitrate-N values were consistently much higher than those for water-leachable inorganic P. This indicated that mineralization was occurring at a faster rate for nitrate-N than for water-leachable inorganic P.

Incubation of Soil at Various Water Contents Under Atmospheres of Air and Dinitrogen Gas

Data from the incubation of rice soil at five moisture contents and under atmospheres of air or dinitrogen gas are tabulated in Table 21. The mean for nitrate-N extracted from those samples incubated under dinitrogen gas was significantly lower than that from soil incubated aerobically. The redox potentials showed small difference between the two atmospheres and were well below that for aerobic soil which is approximately 660 mv at pH 7. The degree of nitrate disappearance was not very great, showing that denitrification under these experimental conditions was not excessive. There was no significant difference between the treatment means for water-soluble inorganic P. This result probably occurred because the redox was being poised by nitrate and there was no reduction of ferric-Fe to ferrous-Fe.

Table 21. Incubation of soil from a rice paddy on Pahokee muck at five moisture levels under two atmospheres.

Moisture content	Atmosphere	Redox pH 7	NO_3-N	pH	P
%,w/w		mv	g kg^{-1}		mg kg^{-1}
175	Air	368	970	6.80	6.90
	N_2	353	870	7.15	5.61
200	Air	355	910	6.61	5.94
	N_2	331	830	7.20	5.15
225	Air	371	880	6.91	5.53
	N_2	346	870	7.29	5.31
250	Air	379	960	7.09	5.11
	N_2	353	880	7.35	5.34
555	Air	380	880	7.17	5.38
	N_2	322	840	7.48	6.64
823	Air	347	910	7.52	5.63
	N_2	336	880	7.74	5.85
Mean	Air	367†	920‡	7.02‡	5.58
	N_2	340	860	7.37	5.65

† Interaction between water content and atmosphere significant at the 1% level.

‡ Significant difference at the 5% level by Duncan's Multiple Range Test.

General Discussion

The Histosols of the Everglades Agricultural Area are cropped mainly to sugarcane, truck crops, and pasture, as they have been for many years. More recently, rice has been introduced into the area. This study was initiated to evaluate some of the effects of these various cropping systems on the inorganic and organic P fractions of Pahokee muck at the AREC, Belle Glade, Florida.

Before discussing the P in these soils, it should be mentioned that the depth distributions of bulk density (Fig. 4) showed very apparent effects of soil tillage under these different cropping systems. These differences were reflected in a very highly significant field x depth interaction for bulk density. This indicated that the bulk density changed differently among the fields in a manner which was statistically significant. However, it was evident from the shape of the bulk density versus depth distributions that there were three main trends in the data. The first was found in the three pastures and the Virgin field, which had received little or no cultivation. The second was characteristic of the Cane 1, Cane 2, and Rice profiles, and indicated that cultivation had resulted in high bulk densities at the 0.10 to 0.15 m depth due to compaction. The third trend was found in the more intensively cultivated fields, that is, the Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields, in which the maximum bulk density occurred between depths of 0.15 to 0.29 m. Since the bulk density was variable with depth and between fields, and the cores were sectioned by depth, the concentration of the elements studied were expressed on a soil volume basis as suggested by Tate (1979) and Lucas (1982).

Total P in the samples of Pahokee muck studied was determined after ignition. The field x depth interaction for these data was significant at the 0.1% level. This indicated that past and present P fertilization, soil tillage, and cropping of the fields resulted in differential changes in total P with depth. Since the field x depth interaction was significant, total P at each of the depths sampled was compared between fields and total P in each of the fields was compared by depths (Table A-24). The depth distributions of total P for the fields is shown in Fig. 15. A large accumulation of total P occurred in the surface 0.15 m of the pastures. This resulted from deposition of P-containing waste by grazing cattle and surface dusting with fertilizer P. Below 0.15 m, levels of total P in the pastures and the Virgin soil were very similar, which indicated that there was very little downward movement of total P by natural forces. In the Horticulture field, high levels of total P throughout the profile resulted from high levels of P fertilization (Forsee, 1953) and frequent deep tillage. Similar trends were apparent in the Fallow, Vegetable 1, and Vegetable 2 profiles. In the Cane 1 and Cane 2 fields, lower levels of applied fertilizer P (Gascho and Kidder, 1979) and less frequent tillage resulted in lower levels of total P, particularly below a depth of 0.22 m. Uptake of P by the sugarcane crop, which has a large biomass, is certainly another factor to be considered.

Of the other elements determined in the ashed samples, only Cu was highly correlated with total P. The r^2 value was 0.72. Historically, the addition of Cu to Everglades Histosols was found to relieve the symptoms of Cu deficiency in crops growing on these soils (Lucas, 1982). The depth distributions of total Cu for the fields appear in Fig. 18.

Since the Virgin soil had received no fertilizer, low levels of Cu occurred throughout the profile. However, the addition of Cu to the cultivated fields was evident from much higher levels of total Cu, especially above a depth of 0.22 m. The depth distributions of total Cu were very similar to those of total P (Fig. 15) for the cultivated fields. This finding substantiates the interpreted effects of fertilization and tillage on the depth distributions of total P in these fields.

Of the three reagents used to extract inorganic P from the samples of Pahokee muck, hot 0.1N HCl extracted the most. Wet digestion of aliquots of these deeply colored extracts showed that their content of total P was substantially greater than their content of inorganic P. In other words, the hot 0.1N HCl also extracted some of the organic P from the muck samples.

Analysis of variance showed that there was a significant field x depth interaction for total P extracted by hot 0.1N HCl. The depth distributions of total P extracted by this reagent (Fig. 12) were very similar to those of total P determined by ignition (Fig. 15) with respect to shape. In addition, similar values of total P resulted from the acid extraction and ignition methods for samples in the top 0.10 m of the pastures, throughout the Horticulture field, and below 0.29 m in the remaining fields. Values determined by both methods were very highly correlated with a r^2 value of 0.93. These findings indicated that a portion (48 to 105%) of the total P in the profiles of Pahokee muck studied was susceptible to extraction with hot 0.1N HCl.

Since the hot 0.1N HCl extracted the most inorganic P, amounts extracted by this reagent were used as estimates of the total inorganic P in the muck samples. Subtraction of these values from corresponding amounts of total P determined by ignition gave estimates of total organic P. Analysis of variance indicated that there was a very highly significant field x depth interaction for total organic P. The nature of the interaction can be seen in Fig. 16, which shows the depth distributions of total organic P. In the intensively cultivated Horticulture, Fallow, Vegetable 1, and Vegetable 2 fields, levels of total organic P increased sharply with depth in the top 0.22 or 0.29 m and then decreased with depth to 0.43 m. In the remaining fields, total organic P decreased somewhat uniformly with depth from 0 to 0.43 m. Higher levels of total organic P in the surface 0.15 m of the pastures resulted from deposition of organic P in waste from grazing cattle. In each of the depths below 0.15 m, there was no significant difference in levels of total organic P determined for the three pastures and the Virgin soil (Table A-25). This indicated that there had been little downward transport of total organic P in the pastures. Total organic P in the Cane 1, Cane 2, and Rice profiles was not affected by past fertilization and soil tillage, since levels at each depth were not significantly different from corresponding values in the Virgin profile. However, these factors caused significant increases in the level of total organic P below 0.10 and 0.15 m in the Fallow and Horticulture fields, respectively. Although the Fallow field had been uncropped for several years before sampling, the depth distribution of total Cu in this field (Fig. 18) indicated that it had been heavily fertilized in the past.

Organic P extracted by hot 0.1N HCl was calculated as the difference between total P and inorganic P extracted by this reagent. Analysis of variance showed that the field x depth interaction for this category of soil P was very highly significant. The depth distributions for organic P extracted by hot 0.1N HCl are shown in Fig. 13. The effects of intensive soil management resulted in higher levels of acid-extractable organic P throughout the Horticulture profile and from the 0.10 to 0.29 m depth of the Vegetable 1 and Vegetable 2 fields. More than 75% of the total organic P in the top 0.15 m of these fields was acid-extractable (Table 13), compared to percentages of 37, 35, 32, and 25 for the Virgin, Cane 1, Cane 2, and Rice fields, respectively.

Residual organic P was calculated as the difference between total P determined by ignition and total P extracted by hot 0.1N HCl. Analysis of variance indicated that the field x depth interaction had a significance probability for the F value (PR>F) of 0.367, which was not significant. This meant that residual organic P changed between the fields in a similar manner for all of the depths. Moreover, this form of P changed with depth in a similar manner for all of the fields. Consequently, differences between the means of residual organic P for each field (averaged over depths) and between the means for each depth (averaged over fields) were further analyzed (Table 12). Intensive soil management resulted in significantly lower mean values of residual organic P in the Horticulture, Vegetable 1, and Vegetable 2 fields. The reason for this decrease and the concomitant increase in hot 0.1N HCl-extractable organic P in these fields should be further researched.

The field x depth interaction for inorganic P extracted by hot 0.1N HCl had a PR>F of 0.190, which was not significant. Mean values of total inorganic P were significantly high at 0 to 0.10 m and decreased with depth to 0.43 m (Table 11). Past P fertilization and deep tillage resulted in a significantly high mean level of total inorganic P in the

Horticulture field. Lower applications of P to sugarcane resulted in levels of total inorganic P in the Cane 1 and Cane 2 fields which were not significantly greater than that in the Virgin soil. In the top 0.15 m of the Horticulture field, total inorganic P was 72% of the total soil P (Table 13). However, percentages were 24, 35, and 34 in the Virgin, Cane 1, and Cane 2 fields, respectively.

An increase in solution to soil ratio from 10:1 to 100:1 in the extraction of muck samples with double acid, resulted in a six-fold increase in the amount of inorganic P extracted (Table A-4). Since larger ratios resulted in slight increases in inorganic P extracted, the 100:1 ratio was selected. The field x depth interaction for inorganic P extracted by double acid had a PR>F of 0.777, which was not significant. Although mean values of inorganic P extracted by double acid were less, they decreased with depth and varied between fields (Table 10) in much the same manner as did those by hot 0.1N HCl (Table 11). However, an abnormally low mean value occurred in the Virgin profile. Inorganic P extracted by double acid accounted for 30 to 59% of the total inorganic P in the 0 to 0.15 m depth of the cultivated fields, compared to 9% in the Virgin field (Table 13). The correlation of inorganic P extracted by these two reagents from all of the soil samples studied was very highly significant with a r^2 value of 0.93. This suggests that double acid has a potential as a soil test for evaluating total inorganic P in the Everglades Histosols, particularly in the cultivated fields.

Water-soluble P is the current method for testing Everglades soils for plant-available P and it has been used for several decades (Forsee, 1950). In the present study, it was found that increasing the solution to soil extraction ratio from 10:1 to 100:1 resulted in a six-fold increase in the amounts of inorganic P extracted by water (Table A-1). Further increases were slight when the ratio was increased to 300:1. Duration of shaking time also affected the amounts of inorganic P extracted as the water to soil ratio was increased from 100:1 to 300:1 (Tables A-3 and A-4). This indicated that uniform extracting conditions, with respect to ratio and time of shaking, were required for comparisons between samples. It was also found that some factor in the slightly colored water extracts interfered with the ascorbic acid-ammonium molybdate colorimetric method of John (1970). However, this interference was removed by clearing the extracts with activated carbon (Fig. 2a).

The field x depth interaction for water-extractable inorganic P was barely not significant with a PR>F of 0.054. A larger number of samples might have resulted in more evidence that a field x depth interaction did exist. Mean values of inorganic P decreased with depth (Table 9). Effects of past P fertilization were evident, since the Horticulture field had a significantly high level of water-extractable inorganic P. The mean value for the Virgin profile was greater than that for the Cane 2, Fallow, and Vegetable 2 profiles. Inorganic P extracted by water accounted for 2.8 to 4.1% of the total inorganic P in the 0 to 0.15 m depth of the cultivated fields, compared to 13.6% in the Virgin field (Table 13). Similar availability of water-soluble P in virgin muck from the Everglades was reported by Allen and Kidder (1952). These findings indicate that extraction with water provides a good estimate of plant-available or labile inorganic P in these soils.

Some of the factors affecting the level of water-extractable inorganic P in Pahokee muck were investigated in a series of laboratory experiments. Incubation of soil samples from the Vegetable 2 (Fig. 21) and Virgin (Fig. 23) fields with water-soluble inorganic P, added at rates of 20, 40, and 80 mg P kg^{-1} of soil, resulted in a rapid rate of depletion of water-extractable inorganic P during the first 5 days. Between 5 and 48 days of incubation, amounts of water-extractable inorganic P tended to stabilize at levels proportional to the rates of added P. These data showed that some mechanism in the soil was rendering the added P less water-extractable with time. This mechanism might be microbial immobilization, but it is more likely that physical adsorption and chemical precipitation of the added P were occurring. A similar incubation of Vegetable 2 and Virgin soil with added corn stover (Fig. 22 and 24, respectively) resulted in a more rapid rate of depletion of water-extractable inorganic P during the first 5 days due to stimulated microbial activity. Between 10 and 48 days of incubation, amounts of water-extractable inorganic P slowly increased. During this time, levels were also proportional to the rates of added P.

The replenishment of water-extractable inorganic P may have resulted from the lysis of cells during the decline of the microbial population; mineralization of organic P in the soil itself or in the added corn stover; dissolution of slightly soluble inorganic phosphates by microorganisms or in response to a displaced equilibrium between soluble and slightly soluble fractions; and desorption of inorganic P due to a displaced equilibrium between inorganic P in the solution and sorbed phases.

A subsequent experiment was designed to investigate further the maintenance of an equilibrium level of water-extractable inorganic P by Pahokee muck. Soil samples from the Vegetable 2, Rice, and Fallow fields were extracted with water, transferred to a membrane filter, and leached periodically with water during a 59-day incubation. Levels of inorganic P in the leachates were fairly constant with time for each soil (Fig. 25). These data suggested that, for the soils studied, the larger the amount of total P, the higher was the amount of P maintained as water-extractable or water-leachable inorganic P. This finding also demonstrated that there was a rather stable regeneration of water-leachable inorganic P during the 59 days of incubation.

Another experiment showed that incubation of surface soil samples from the Rice paddy at gravimetric water contents ranging 175 to 823% had no effect on the level of water-soluble inorganic P (Table 21). In this study, there was no effect of imposed air or dinitrogen atmosphere on level of P in this form. Measurement of redox potentials showed that all samples were anaerobic and were apparently poised by the high nitrate levels present. However, further research in this regard should center on changes in solubility of phosphates in anaerobic subsoils.

CONCLUSIONS

(1) Soil tillage and P fertilization of the sampled fields of Pahokee muck resulted in differential changes in total P with depth and between fields. This was substantiated by the depth distributions of total Cu for these fields. Of all the cations determined in the ash, Cu showed the strongest correlation with total P.

(2) Total P extracted by hot 0.1N HCl was very highly correlated with total P determined by ignition. The hot acid extracted more than 48% of the total P in the profiles studied.

(3) Levels of total organic P at each depth sampled in the profiles of fields cropped to sugarcane and rice were not significantly different than those at corresponding depths in a virgin muck. However, past intensive fertilization and soil tillage resulted in significant increases in levels of total organic P below 0.10 and 0.15 m in fields that were left fallow and used for horticulture, respectively.

(4) Intensive soil management resulted in high levels of hot 0.1N-extractable organic P throughout the Horticulture profile and from 0.10 to 0.29 m depth of the Vegetable 1 and Vegetable 2 fields.

(5) Low mean values of residual organic P resulted from intensive cultivation of the Horticulture, Vegetable 1, and Vegetable 2 fields. However, these decreases were accompanied by increases in the hot 0.1N HCl-extractable organic P.

(6) For all fields, there was a decrease with depth in inorganic P extracted by hot 0.1N HCl. A high mean value of this total inorganic P in the Horticulture field and low mean levels in the Cane 1 and Cane 2 fields reflected past applications of fertilizer P.

(7) Inorganic P extracted by double acid (solution to soil ratio of 100:1) was very highly correlated with inorganic P extracted by hot 0.1N HCl. The former accounted for 30 to 59% of the latter in the top 0.15 m of the cultivated fields. This suggested that a soil test with double acid would be a good evaluation of the total inorganic P in cultivated Everglades Histosols.

(8) Inorganic P extracted by water (solution to soil ratio of 100:1) accounted for 2.8 to 4.1% of the inorganic P extracted by hot 0.1N HCl in the top 0.15 m depth of the cultivated fields, compared to 13.6% in the Virgin field, and provided a good estimate of labile inorganic P.

(9) Rapid depletion of water-soluble inorganic P added to samples of Pahokee muck occurred during the first 5 days of incubation. Between 5 and 48 days, amounts of water-extractable inorganic P tended to stabilize at levels proportional to the rates of added P. The presence of added corn stover stimulated microbial activity and increased the initial rate of disappearance of added inorganic P. Between 10 and 48 days of incubation, however, amounts of water-extractable inorganic P slowly increased with time at levels proportional to the rates of added P.

(10) Repeated leachings of water-extracted samples of muck from three fields showed that there was a rather stable regeneration of water-leachable inorganic P with time in proportion to levels of either total soil P or initial levels of water-extractable inorganic P.

(11) A further study with soil at various water contents, under either air or dinitrogen atmospheres, showed no change in water-extractable inorganic P because high levels of nitrate poised the redox potential.

APPENDIX

Table A-1. The effect of solution to soil ratio on inorganic P, Ca, Mg, K, and pH of water extracts from the top 0.15 m of a vegetable field on Pahokee muck.†

Solution to soil ratio	Inorganic P	Ca	Mg	K	pH of extract
(v/w)	mg kg^{-1}				
10	3.27	470	140	100	7.23
15	4.67	470	150	110	7.20
20	6.26	460	150	120	7.20
50	13.1	450	170	140	6.95
75	17.0	480	200	150	6.96
100	19.2	500	200	150	7.04
150	20.2	560	220	250	7.00
200	23.0	580	250	160	7.00
250	26.2	620	270	180	7.00
300	24.4	570	240	180	6.87

† Samples were shaken at high speed for 25 minutes with 150 ml of water without prior blending. The extracts were filtered through Whatman No. 42 paper and a 0.2 µ membrane. Analysis for P was done without clearing the extract with activated carbon.

Table A-2. The effect of solution to soil ratio and shaking time on inorganic P, Ca, Mg, K, and pH of water extracts from the top 0.15 m of a vegetable field on Pahokee muck.†

Solution to soil ratio	Inorganic P	Ca	Mg	K	pH of extract
(v/w)	mg kg^{-1}				
		Shaking time, 0.5 hr			
100	24.5	590	200	160	7.16
200	38.0	640	240	200	6.86
300	42.0	780	300	210	6.80
		Shaking time, 2 hr			
100	29.3	690	230	160	7.12
200	40.0	680	280	180	7.02
300	44.5	810	330	210	7.05
		Shaking time, 4 hr			
100	38.5	740	270	180	7.40
200	43.4	860	320	180	7.23
300	44.0	990	390	210	7.19
400	51.3	1300	520	200	7.30
		Shaking time, 8 hr			
100	37.8	810	320	180	7.52
200	42.3	980	380	220	7.48
300	56.0	1100	450	240	7.17
400	56.0	1400	560	240	7.36

† Samples were blended, shaken at low speed with 150 ml of water, and the extracts were filtered through a 0.2 μ membrane. Prior to analysis for P, an aliquot of the extract was cleared with activated carbon.

Table A-3. The effect of solution to soil ratio and shaking time on inorganic P, Ca, Mg, K, Fe, and pH of water extracts from the top 0.15 m of a virgin field on Pahokee muck.†

Solution to soil ratio	Inorganic P	Ca	Mg	K	Fe	pH of extract
(v/w)	mg kg^{-1}	g kg^{-1}		mg kg^{-1}		
			Shaking time, 1 hr			
100	22.7	1.9	310	470	20	5.56
200	26.5	1.8	330	450	20	6.16
300	28.6	1.8	350	450	30	5.52
400	25.0	1.8	320	520	0	6.62
			Shaking time, 2 hr			
100	26.8	2.0	320	490	20	5.85
200	30.1	1.8	350	460	20	6.07
300	34.3	1.8	320	440	30	5.66
400	47.8	1.9	360	560	0	5.82
			Shaking time, 4 hr			
100	32.2	2.0	330	490	20	5.84
200	35.1	2.1	350	540	20	5.75
300	36.2	1.9	330	480	30	6.39
400	43.8	2.0	340	520	0	6.07

† Samples were blended, shaken at low speed with 150 ml of water, and the extracts were filtered through a 0.2 μ membrane. Prior to analysis for P, an aliquot of the extract was cleared with activated carbon.

Table A-4. The effect of solution to soil ratio on inorganic P, Ca, Al, Fe, Cu, and pH of double acid extracts from the top 0.15 m of a vegetable field on Pahokee muck.†

Solution to soil ratio	Inorganic P	Ca	Al	Fe	Cu	pH of extract
(v/w)	mg kg^{-1}	g kg^{-1}		mg kg^{-1}		
10	140	12.0	0	3	0.2	4.25
35	592	41.6	350	30	1.4	2.30
75	730	47.6	830	130	5.3	1.58
100	812	50.3	1000	180	7.1	1.48
150	885	48.3	1000	290	11	1.39
200	796	49.3	1000	360	12	1.36
250	909	54.1	1000	450	15	1.35
300	734	53.1	1000	510	15	1.33
blank	0	0	0	0	0	1.29

† Samples were shaken at low speed for 25 minutes with 50 ml of double acid and the extracts were filtered through Whatman No. 42 paper.

Table A-5. Bulk density of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, Mg m^{-3}	0.249	0.340	0.326	0.219	0.210	0.194	0.178
DMRT, depths	bc	s	ab	c	c	c	c
DMRT, fields	c	b	cd	e	c	c	b
				Pasture 2			
Mean, Mg m^{-3}	0.272	0.320	0.344	0.289	0.236	0.203	0.195
DMRT, depths	abcd	ab	a	abc	bcd	cd	d
DMRT, fields	abc	b	cd	cde	c	c	b
				Pasture 3			
Mean, Mg m^{-3}	0.264	0.310	0.359	0.254	0.200	0.155	0.153
DMRT, depths	bc	ab	a	bc	cd	d	d
DMRT, fields	bc	b	bcd	de	c	c	b
				Virgin			
Mean, Mg m^{-3}	0.317	0.333	0.294	0.223	0.213	0.196	0.149
DMRT, depths	a	a	ab	bc	bc	c	c
DMRT, fields	abc	b	d	e	c	c	b
				Cane 1			
Mean, Mg m^{-3}	0.287	0.359	0.410	0.315	0.266	0.200	0.136
DMRT, depths	bcd	ab	a	bc	cd	de	e
DMRT, fields	abc	ab	abc	bcd	c	c	b
				Cane 2			
Mean, Mg m^{-3}	0.351	0.394	0.442	0.358	0.362	0.241	0.149
DMRT, depths	a	a	a	a	a	b	c
DMRT, fields	ab	ab	ab	abc	b	bc	b
				Rice			
Mean, Mg m^{-3}	0.368	0.444	0.474	0.352	0.276	0.168	0.185
DMRT, depths	bc	ab	a	cd	d	e	e
DMRT, fields	a	a	a	abc	c	c	b

Table A-5-continued.

Factor†	Depth sampled, m 0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, Mg m^{-3}	0.289	0.323	0.356	0.385	0.432	0.391	0.317
DMRT, depths	c	bc	abc	ab	a	ab	bc
DMRT, fields	abc	b	bcd	ab	ab	a	a
				Horticulture			
Mean, Mg m^{-3}	0.259	0.289	0.335	0.409	0.467	0.441	0.364
DMRT, depths	e	de	cde	abc	a	ab	bcd
DMRT, fields	bc	b	cd	a	a	a	a
				Vegetable 1			
Mean, Mg m^{-3}	0.329	0.356	0.382	0.421	0.412	0.307	0.218
DMRT, depths	ab	ab	ab	a	a	b	c
DMRT, fields	abc	ab	abcd	a	ab	b	b
				Vegetable 2			
Mean, Mg m^{-3}	0.316	0.359	0.402	0.445	0.403	0.217	0.192
DMRT, depths	b	ab	ab	a	ab	c	c
DMRT, fields	abc	ab	abc	a	ab	c	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-6. Weight of ash per unit volume of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, kg Ash m^{-3}	44.2	68.9	61.2	37.7	36.2	32.3	27.6
DMRT, depths	bc	a	ab	c	c	c	c
DMRT, fields	ab	ab	abc	ef	e	bc	c
Pasture 2							
Mean, kg Ash m^{-3}	51.0	62.6	70.0	66.6	46.9	37.8	36.2
DMRT, depths	abc	ab	a	ab	bc	c	c
DMRT, fields	ab	abc	ab	bcd	de	bc	c
Pasture 3							
Mean, kg Ash m^{-3}	44.2	53.6	62.6	56.6	38.5	25.1	24.3
DMRT, depths	abc	ab	a	ab	bcd	cd	d
DMRT, fields	ab	bc	abc	cde	e	c	c
Virgin							
Mean, kg Ash m^{-3}	42.1	47.2	43.1	33.6	32.5	29.9	23.1
DMRT, depths	ab	a	ab	ab	ab	ab	b
DMRT, fields	b	c	c	f	e	bc	c
Cane 1							
Mean, kg Ash m^{-3}	42.2	52.6	59.2	46.5	40.0	28.9	16.4
DMRT, depths	ab	a	a	ab	ab	bc	c
DMRT, fields	b	bc	bc	def	e	bc	c
Cane 2							
Mean, kg Ash m^{-3}	54.2	63.8	71.8	59.5	60.7	38.8	20.2
DMRT, depths	ab	a	a	a	a	b	c
DMRT, fields	ab	abc	ab	cd	cd	bc	c
Rice							
Mean, kg Ash m^{-3}	63.9	77.3	81.0	58.6	43.9	36.8	54.6
DMRT, depths	abc	ab	a	bcd	de	e	cde
DMRT, fields	a	a	a	cd	de	bc	b

Table A-6-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Fallow							
Mean, kg Ash m^{-3}	56.2	61.2	66.1	75.2	85.5	76.3	58.0
DMRT, depths	b	b	ab	ab	a	ab	b
DMRT, fields	ab	abc	ab	abc	ab	a	ab
Horticulture							
Mean, kg Ash m^{-3}	54.7	63.7	72.4	89.5	95.8	89.5	74.9
DMRT, depths	d	cd	bcd	ab	a	ab	bc
DMRT, fields	ab	abc	ab	a	a	a	a
Vegetable 1							
Mean, kg Ash m^{-3}	57.1	60.4	63.4	69.8	68.7	48.7	32.3
DMRT, depths	ab	ab	ab	a	ab	bc	c
DMRT, fields	ab	abc	ab	abc	bc	b	c
Vegetable 2							
Mean, kg Ash m^{-3}	56.2	64.0	72.0	81.4	71.5	33.1	28.7
DMRT, depths	b	ab	ab	a	ab	c	c
DMRT, fields	ab	abc	ab	ab	bc	bc	c

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-7. Percent volumetric water content of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, v/v	45.0	58.5	65.8	60.5	69.3	72.8	70.2
DMRT, depths	d	c	abc	bc	ab	a	ab
DMRT, fields	ab	abc	a	a	a	ab	cd
				Pasture 2			
Mean, v/v	42.2	48.8	53.8	51.0	54.3	58.6	62.7
DMRT, depths	c	bc	ab	bc	ab	ab	a
DMRT, fields	abc	cd	b	abc	bcd	cd	cde
				Pasture 3			
Mean, v/v	49.1	52.3	55.4	43.7	45.6	49.5	53.6
DMRT, depths	ab	ab	a	b	ab	ab	ab
DMRT, fields	a	bc	b	bc	d	d	e
				Virgin			
Mean, v/v	31.9	41.8	46.3	42.6	49.8	54.5	52.4
DMRT, depths	c	b	ab	b	ab	a	ab
DMRT, fields	cd	de	bc	c	cd	d	e
				Cane 1			
Mean, v/v	47.6	59.7	69.7	59.9	67.1	72.6	65.5
DMRT, depths	c	b	ab	b	ab	a	ab
DMRT, fields	a	ab	a	a	a	ab	cd
				Cane 2			
Mean, v/v	45.3	57.4	66.5	53.9	54.1	58.7	59.6
DMRT, depths	c	ab	a	bc	bc	ab	a
DMRT, fields	ab	abc	a	ab	bcd	cd	de
				Rice			
Mean, v/v	52.8	64.2	67.1	57.0	58.9	66.6	66.5
DMRT, depths	b	a	a	ab	ab	a	a
DMRT, fields	a	a	a	a	abc	bc	cd

Table A-7-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, v/v	29.5	33.2	36.9	49.9	66.1	67.7	72.6
DMRT, depths	c	c	c	b	a	a	a
DNRT, fields	d	e	c	abc	a	bc	bc
				Horticulture			
Mean, v/v	30.7	36.3	41.9	55.9	65.3	67.8	72.1
DMRT, depths	d	cd	c	b	ab	a	a
DMRT, fields	d	e	c	a	a	bc	bc
				Vegetable 1			
Mean, v/v	36.7	40.9	45.1	52.0	63.8	76.8	86.2
DMRT, depths	d	d	cd	c	b	a	a
DMRT, fields	bcd	de	bc	abc	ab	ab	a
				Vegetable 2			
Mean, v/v	35.1	41.0	46.9	57.9	65.6	80.7	82.0
DMRT, depths	d	cd	c	b	b	a	a
DMRT, fields	bcd	de	bc	a	a	a	ab

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-8. Main effects of fields and depths on the pH of water extracts from Pahokee muck.

Field	pH†	Depth	pH†
		m	
Pasture 1	8.35 a	0 to 0.05	7.11 a
Virgin	6.15 f	0.05 to 0.10	7.16 a
Cane 2	7.10 c	0.10 to 0.15	7.23 a
Rice	7.07 c	0.15 to 0.22	7.12 a
Fallow	6.85 d	0.22 to 0.29	7.07 a
Horticulture	7.87 b	0.29 to 0.36	7.18 a
Vegetable 2	6.70 e	0.36 to 0.43	7.23 a

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

Table A-9. Inorganic P extracted by water from Pahokee muck from seven fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g P m^{-3}	25.2	16.1	4.95	2.60	2.81	3.28	1.81
DMRT, depths	a	b	c	c	c	c	c
DMRT, fields	a	ab	b	b	b	b	b
				Virgin			
Mean, g P m^{-3}	9.74	9.73	7.07	4.35	3.24	2.67	2.10
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	bc	b	b	b	b	b
				Cane 2			
Mean, g P m^{-3}	3.22	4.36	5.19	2.14	2.19	1.65	0.76
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	c	b	b	b	b	b
				Rice			
Mean, g P m^{-3}	4.82	8.87	9.32	9.14	5.04	1.73	0.76
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	bc	b	b	b	b	b
				Fallow			
Mean, g P m^{-3}	3.79	4.44	5.04	4.18	3.52	2.60	2.23
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	c	b	b	b	b	b
				Horticulture			
Mean, g P m^{-3}	18.0	20.5	22.8	20.2	17.1	15.0	10.1
DMRT, depths	ab	a	a	a	ab	ab	b
DMRT, feilds	a	a	a	a	a	a	a
				Vegetable 2			
Mean, g P m^{-3}	5.71	6.18	6.67	5.98	4.75	1.29	0.61
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	c	b	b	b	b	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-10. Calcium extracted by water from Pahokee muck from seven fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g Ca m^{-3}	190	220	260	260	270	260	200
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	b	b	bc	c	c	bc
				Virgin			
Mean, g Ca m^{-3}	300	420	470	430	480	490	440
DMRT, depths	b	a	a	a	a	a	a
DMRT, fields	a	a	a	a	a	a	a
				Cane 2			
Mean, g Ca m^{-3}	170	200	190	150	170	180	140
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	b	bc	d	d	cd	cd
				Rice			
Mean, g Ca m^{-3}	210	160	160	150	110	100	75
DMRT, depths	a	ab	ab	ab	b	b	b
DMRT, fields	b	b	c	d	d	d	d
				Fallow			
Mean, g Ca m^{-3}	160	180	200	290	400	390	370
DMRT, depths	c	c	c	b	a	a	ab
DMRT, fields	b	b	bc	b	ab	b	a
				Horticulture			
Mean, g Ca m^{-3}	130	150	170	190	180	190	170
DRMT, depths	a	a	a	a	a	a	a
DMRT, fields	b	b	bc	cd	d	cd	c
				Vegetable 2			
Mean, g Ca m^{-3}	170	210	250	310	330	350	280
DMRT, depths	b	cd	bcd	ab	ab	a	abc
DMRT, fields	b	b	bc	b	bc	b	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-11. Magnesium extracted by water from Pahokee muck from seven fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g Mg m^{-3}	44	44	44	37	36	36	31
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bc	b	cd	cd	c	c
				Virgin			
Mean, g Mg m^{-3}	73	80	68	50	49	53	52
DMRT, depths	a	a	ab	c	c	bc	bc
DMRT, fields	a	a	a	bc	bc	b	b
				Cane 2			
Mean, g Mg m^{-3}	41	43	43	29	33	33	29
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bc	b	d	cd	c	c
				Rice			
Mean, g Mg m^{-3}	74	51	40	30	20	25	20
DMRT, depths	a	b	bc	cd	d	cd	d
DMRT, fields	a	bc	b	d	d	c	c
				Fallow			
Mean, g Mg m^{-3}	30	34	38	48	61	58	58
DMRT, depths	c	bc	bc	ab	a	a	a
DMRT, fields	c	c	b	bc	b	b	ab
				Horticulture			
Mean, g Mg m^{-3}	52	58	65	74	79	77	71
DMRT, depths	c	bc	abc	ab	a	a	ab
DMRT, fields	b	b	a	a	a	a	a
				Vegetable 2			
Mean, g Mg m^{-3}	31	41	45	55	60	60	55
DMRT, depths	c	bc	abc	ab	a	a	ab
DMRT, fields	c	bc	b	b	b	b	ab

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-12. Main effects of fields and depths on potassium extracted by water from Pahokee muck.

Field	Extracted K†	Depth	Extracted K†
	g m^{-3}	m	g m^{-3}
Pasture 1	320 a	0 to 0.05	100 a
Virgin	35 b	0.05 to 0.10	110 a
Cane 2	9 b	0.10 to 0.15	100 a
Rice	31 b	0.15 to 0.22	77 a
Fallow	29 b	0.22 to 0.29	69 a
Horticulture	87 b	0.29 to 0.36	57 a
Vegetable 2	46 b	0.36 to 0.43	43 a

† Means not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test.

Table A-13. Iron extracted by water from Pahokee muck from seven fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, g Fe m^{-3}	3	5	5	3	2	2	3
DMRT, depths	ab	a	a	ab	b	b	ab
DMRT, fields	ab	ab	ab	b	ab	ab	a
Virgin							
Mean, g Fe m^{-3}	5	7	6	6	4	3	2
DMRT, depths	abc	a	ab	ab	bcd	cd	d
DMRT, fields	a	a	a	a	a	a	ab
Cane 2							
Mean, g Fe m^{-3}	2	2	5	4	4	3	2
DMRT, depths	b	b	a	ab	ab	ab	b
DMRT, fields	bc	cd	ab	ab	a	a	ab
Rice							
Mean, g Fe m^{-3}	0	0	3	4	0	2	2
DMRT, depths	b	b	a	a	b	ab	ab
DMRT, fields	c	d	bc	ab	b	ab	ab
Fallow							
Mean, g Fe m^{-3}	2	3	2	4	4	4	3
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bc	cd	ab	a	a	a
Horticulture							
Mean, g Fe m^{-3}	0	0	0	2	0	0	0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	d	d	bc	b	b	b
Vegetable 2							
Mean, g Fe m^{-3}	0	0	0	0	2	2	2
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	d	d	c	ab	ab	ab

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-14. Calcium extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, kg Ca m^{-3}	10.2	14.5	15.8	10.9	11.1	10.3	9.00
DMRT, depths	bc	ab	a	bc	bc	bc	c
DMRT, fields	cde	bcd	bcd	de	d	cd	cd
				Pasture 2			
Mean, kg Ca m^{-3}	9.70	12.0	13.7	13.8	12.6	11.1	10.8
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	de	cde	cde	cd	cd	cd	bc
				Pasture 3			
Mean, kg Ca m^{-3}	7.27	9.38	11.6	9.19	8.88	7.86	7.71
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	e	e	de	e	d	de	cd
				Virgin			
Mean, kg Ca m^{-3}	9.98	10.7	10.3	9.05	9.34	9.27	7.52
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cde	de	e	e	d	de	cd
				Cane 1			
Mean, kg Ca m^{-3}	11.0	14.0	16.5	12.0	11.2	8.50	5.17
DMRT, depths	bc	ab	a	ab	bc	cd	d
DMRT, fields	bcde	bcd	bc	cde	d	de	d
				Cane 2			
Mean, kg Ca m^{-3}	15.0	17.0	19.6	15.4	15.6	11.0	5.96
DMRT, depths	b	ab	a	ab	ab	c	d
DMRT, fields	ab	ab	ab	bc	bc	cd	d
				Rice			
Mean, kg Ca m^{-3}	16.9	20.1	21.9	16.3	11.8	5.51	5.66
DMRT, depths	b	ab	a	b	c	d	d
DMRT, fields	a	a	a	abc	cd	e	d

Table A-14-continued.

Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
	Depth sampled, m						
				Fallow			
Mean, kg Ca m^{-3}	12.2	13.6	15.1	16.6	19.9	18.0	14.5
DMRT, depths	c	bc	bc	abc	a	ab	bc
DMRT, fields	bcd	bcde	bcd	abc	ab	a	ab
				Horticulture			
Mean, kg Ca m^{-3}	12.7	14.9	16.9	19.9	22.7	22.1	16.6
DMRT, depths	c	c	bc	ab	a	a	bc
DMRT, fields	abcd	bcd	bc	a	a	a	a
				Vegetable 1			
Mean, kg Ca m^{-3}	14.5	15.4	16.4	18.5	18.5	13.8	9.59
DMRT, depths	ab	ab	ab	a	a	b	c
DMRT, fields	abc	bc	bc	ab	b	c	cd
				Vegetable 2			
Mean, kg Ca m^{-3}	13.8	16.4	18.9	19.8	18.3	9.69	7.11
DMRT, depths	b	ab	a	a	a	c	c
DMRT, fields	abcd	abc	ab	ab	b	cde	cd

[†] Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-15. Aluminum extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g Al m^{-3}	280	430	430	180	150	100	80
DMRT, depths	b	a	a	bc	bc	c	c
DMRT, fields	ab	a	ab	d	cd	b	c
				Pasture 2			
Mean, g Al m^{-3}	300	390	480	470	290	120	150
DMRT, depths	bc	ab	a	a	bc	cd	d
DMRT, fields	ab	ab	a	a	bcd	b	bc
				Pasture 3			
Mean, g Al m^{-3}	150	250	370	350	220	90	90
DMRT, depths	cd	abc	a	ab	bcd	d	d
DMRT, fields	b	bc	abc	abc	bcd	b	c
				Virgin			
Mean, g Al m^{-3}	200	200	200	200	150	100	80
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	c	d	cd	cd	b	c
				Cane 1			
Mean, g Al m^{-3}	200	300	300	250	140	80	60
DMRT, depths	abc	a	a	ab	bc	c	c
DMRT, fields	ab	abc	bcd	bcd	d	b	c
				Cane 2			
Mean, g Al m^{-3}	200	250	300	250	250	130	70
DMRT, depths	abc	ab	a	ab	ab	bc	c
DMRT, fields	ab	bc	bcd	bcd	bcd	b	c
				Rice			
Mean, g Al ,$^{-3}$	330	420	440	300	200	330	390
DMRT, depths	ab	a	a	ab	b	ab	a
DMRT, fields	a	a	ab	bcd	bcd	a	a

Table A-15-continued.

Factor†	Depth sampled, m 0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Fallow							
Mean, g Al m^{-3}	300	330	360	390	460	380	250
DMRT, depths	b	ab	ab	ab	a	ab	b
DMRT, fields	ab	abc	abc	ab	a	a	b
Horticulture							
Mean, g Al m^{-3}	250	200	250	300	350	400	250
DMRT, depths	bc	c	bc	abc	ab	a	bc
DMRT, fields	ab	c	cd	bcd	ab	a	b
Vegetable 1							
Mean, g Al m^{-3}	150	200	200	300	250	150	90
DMRT, depths	bc	abc	abc	a	ab	bc	c
DMRT, fields	b	c	d	bcd	bcd	b	c
Vegetable 2							
Mean, g Al m^{-3}	200	250	300	350	300	60	160
DMRT, depths	b	ab	ab	a	ab	c	bc
DMRT, fields	ab	bc	bcd	abc	bc	b	bc

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-16. Iron extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, g Fe m^{-3}	91	130	130	86	76	59	77
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a
Pasture 2							
Mean, g Fe m^{-3}	110	140	160	110	110	89	57
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a
Pasture 3							
Mean, g Fe m^{-3}	120	170	220	100	76	58	42
DMRT, depths	ab	ab	a	ab	b	b	b
DMRT, fields	ab	ab	b	b	b	ab	a
Virgin							
Mean, g Fe m^{-3}	100	120	120	83	70	56	36
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	b	a
Cane 1							
Mean, g Fe m^{-3}	86	110	140	110	100	96	42
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a
Cane 2							
Mean, g Fe m^{-3}	97	110	130	140	390	200	49
DMRT, depths	bc	bc	bc	bc	a	b	c
DMRT, fields	ab	b	bc	b	a	a	a
Rice							
Mean, g Fe m^{-3}	210	280	540	510	330	160	150
DMRT, depths	bc	bc	a	a	b	c	c
DMRT, fields	a	a	a	a	a	ab	a

Table A-16-continued.

Factor†	Depth sampled, m 0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Fallow							
Mean, g Fe m^{-3}	84	92	100	110	130	130	95
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a
Horticulture							
Mean, g Fe m^{-3}	62	67	74	98	130	160	170
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	b	c	b	b	ab	a
Vegetable 1							
Mean, g Fe m^{-3}	79	91	98	110	110	66	39
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a
Vegetable 2							
Mean, g Fe m^{-3}	87	99	110	130	110	62	72
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	ab	b	bc	b	b	ab	a

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-17. Copper extracted by double acid from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g Cu m^{-3}	1.8	1.9	0.82	0.22	0.21	0	0
DMRT, depths	ab	a	ab	ab	ab	b	b
DMRT, fields	bc	bcd	bc	c	b	b	b
				Pasture 2			
Mean, g Cu m^{-3}	1.6	1.3	0.72	0.15	0	0.09	0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bcd	bc	c	b	b	b
				Pasture 3			
Mean, g Cu m^{-3}	6.6	5.5	1.8	0.13	0.10	0	0
DMRT, depths	a	a	b	b	b	b	b
DMRT, fields	a	a	abc	c	b	b	b
				Virgin			
Mean, g Cu m^{-3}	0.32	0.16	0	0.11	0.22	0.10	0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	d	c	c	b	b	b
				Cane 1			
Mean, g Cu m^{-3}	1.1	1.5	1.3	0.81	0.76	0.43	0.20
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bcd	abc	bc	b	b	b
				Cane 2			
Mean, g Cu m^{-3}	0.70	1.0	0.89	0.72	0.96	0.41	0.15
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	cd	bc	bc	b	b	b
				Rice			
Mean, g Cu m^{-3}	0.93	0.89	0.95	0.51	0.42	0.09	0.10
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	cd	bc	c	b	b	b

Table A-17-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Fallow							
Mean, g Cu m^{-3}	2.1	2.2	2.4	2.4	2.9	2.4	1.5
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	bc	ab	ab	a	a	ab
Horticulture							
Mean, g Cu m^{-3}	2.9	2.9	3.0	3.5	4.3	4.0	3.1
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	b	b	a	a	a	a	a
Vegetable 1							
Mean, g Cu m^{-3}	0.66	0.73	0.78	1.1	0.83	0.37	0.12
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	cd	bc	bc	b	b	b
Vegetable 2							
Mean, g Cu m^{-3}	0.78	0.89	1.0	0.89	0.81	0.22	0.20
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	cd	bc	bc	b	b	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-18. Total P extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g P m^{-3}	631	683	303	149	90.5	90.9	63.3
DMRT, depths	a	a	b	b	b	b	b
DMRT, fields	abc	a	bc	c	c	b	b
				Pasture 2			
Mean, g P m^{-3}	759	689	412	148	105	80.1	70.5
DMRT, depths	a	b	bc	cd	cd	d	d
DMRT, fields	a	a	bc	c	c	b	b
				Pasture 3			
Mean, g P m^{-3}	672	752	464	132	81.4	60.3	70.2
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	ab	a	b	c	c	b	b
				Virgin			
Mean, g P m^{-3}	158	151	114	76.2	65.7	54.2	37.2
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	c	c	c	b	b
				Cane 1			
Mean, g P m^{-3}	182	195	182	111	81.9	42.3	26.1
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	bc	c	c	b	b
				Cane 2			
Mean, g P m^{-3}	151	176	232	141	142	62.2	29.3
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	bc	c	c	b	b
				Rice			
Mean, g P m^{-3}	251	335	381	297	165	59.9	69.6
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	bc	bc	c	b	b

Table A-18-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, g P m^{-3}	265	287	308	320	324	316	199
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	bc	bc	bc	b	b
				Horticulture			
Mean, g P m^{-3}	629	702	774	861	826	812	534
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	abc	a	a	a	a	a	a
				Vegetable 1			
Mean, g P m^{-3}	410	432	453	593	506	203	94.3
DMRT, depths	ab	ab	ab	a	ab	bc	c
DMRT, fields	bcd	ab	bc	ab	b	b	b
				Vegetable 2			
Mean, g P m^{-3}	335	365	394	415	325	64.3	51.8
DMRT, depths	ab	ab	a	a	ab	b	b
DMRT, fields	cd	b	bc	bc	bc	b	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-19. Organic P extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g P m^{-3}	233	242	124	90.8	51.6	51.4	36.8
DMRT, depths	a	a	b	b	b	b	b
DMRT, fields	ab	a	abcd	cd	c	c	b
				Pasture 2			
Mean, g P m^{-3}	310	227	134	78.5	68.1	53.3	46.4
DMRT, depths	a	a	b	b	b	b	b
DMRT, fields	a	a	abcd	d	bc	c	b
				Pasture 3			
Mean, g P m^{-3}	231	245	160	53.7	51.9	42.9	45.5
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	ab	a	abc	d	c	c	b
				Virgin			
Mean, g P m^{-3}	86.1	80.7	59.0	40.9	38.3	27.8	16.8
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cde	bc	d	d	c	c	b
				Cane 1			
Mean, g P m^{-3}	57.4	70.0	91.6	69.8	48.1	18.0	12.7
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	de	c	bcd	d	c	c	b
				Cane 2			
Mean, g P m^{-3}	64.7	67.0	77.4	59.3	58.3	29.9	12.1
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	de	c	bcd	d	c	c	b
				Rice			
Mean, g P m^{-3}	38.5	71.2	65.5	56.1	34.5	14.5	13.5
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	e	c	cd	d	c	c	b

Table A-19-continued.

Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
	Depth sampled, m						
				Fallow			
Mean, g P m^{-3}	137	152	165	172	156	180	108
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bcd	abc	abc	bc	ab	ab	ab
				Horticulture			
Mean, g P m^{-3}	187	202	221	293	205	252	146
DMRT, depths	bc	abc	abc	a	abc	ab	c
DMRT, fields	b	a	a	a	a	a	a
				Vegetable 1			
Mean, g P m^{-3}	168	169	170	282	230	106	64.0
DMRT, depths	bc	bc	bc	a	ab	cd	d
DMRT, fields	bc	ab	ab	a	a	bc	ab
				Vegetable 2			
Mean, g P m^{-3}	197	195	192	202	157	36.6	32.1
DMRT, depths	a	a	a	a	a	b	b
DMRT, fields	b	a	a	ab	ab	c	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-20. Calcium extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, mg Ca m^{-3}	12.9	18.0	19.4	13.9	13.5	12.5	10.7
DMRT, depths	bc	ab	a	bc	bc	bc	c
DMRT, fields	bcd	bc	bc	cd	d	d	cde
Pasture 2							
Mean, mg Ca m^{-3}	12.5	15.4	17.9	16.8	15.9	14.8	14.1
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	bcd	bcd	bcd	cd	cd	bc
Pasture 3							
Mean, mg Ca m^{-3}	9.15	11.1	14.6	12.0	11.4	9.71	9.39
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	d	cd	d	d	de	cde
Virgin							
Mean, mg Ca m^{-3}	13.4	14.1	13.6	11.4	11.7	12.1	9.49
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bcd	cd	d	d	d	de	cde
Cane 1							
Mean, mg Ca m^{-3}	13.7	17.0	20.3	16.5	13.6	10.6	6.23
DMRT, depths	bc	ab	a	ab	bc	cd	d
DMRT, fields	bcd	bc	b	bcd	d	de	e
Cane 2							
Mean, mg Ca m^{-3}	18.0	20.6	22.9	18.9	19.0	13.2	7.45
DMRT, depths	ab	a	a	a	a	b	c
DMRT, fields	abc	ab	ab	bc	bc	d	de
Rice							
Mean, mg Ca m^{-3}	20.2	23.9	26.7	19.6	14.8	6.72	6.89
DMRT, depths	b	ab	a	bc	c	d	d
DMRT, fields	a	a	a	ab	cd	e	de

Table A-20-continued.

Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
	Depth sampled, m						
				Fallow			
Mean, mg Ca m^{-3}	15.9	17.6	19.3	21.3	24.2	22.9	18.6
DMRT, depths	c	bc	abc	abc	a	ab	abc
DMRT, fields	abc	bc	bc	ab	ab	ab	ab
				Horticulture			
Mean, mg Ca m^{-3}	16.3	18.6	20.9	25.1	28.0	27.3	21.2
DMRT, depths	c	c	bc	ab	a	a	bc
DMRT, fields	abc	abc	b	a	a	a	a
				Vegetable 1			
Mean, mg Ca m^{-3}	18.5	20.1	21.5	24.7	24.1	19.0	12.1
DMRT, depths	c	abc	abc	a	ab	bc	d
DMRT, fields	ab	ab	ab	a	ab	bc	cd
				Vegetable 2			
Mean, mg Ca m^{-3}	17.0	19.7	22.3	24.8	22.2	12.1	8.61
DMRT, depths	bc	ab	ab	a	ab	cd	d
DMRT, fields	abc	abc	ab	a	b	de	cde

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-21. Aluminum extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, g Al m^{-3}	310	530	520	220	150	100	80
DMRT, depths	ab	a	a	b	b	b	b
DMRT, fields	ab	a	ab	d	d	b	c
Pasture 2							
Mean, g Al m^{-3}	370	490	620	640	370	190	150
DMRT, depths	bc	ab	a	a	bc	c	c
DMRT, fields	ab	a	ab	a	bcd	b	c
Pasture 3							
Mean, g Al m^{-3}	260	350	590	630	300	90	90
DMRT, depths	bc	b	a	a	bc	c	c
DMRT, fields	b	a	ab	a	bcd	b	c
Virgin							
Mean, g Al m^{-3}	380	450	380	280	220	200	100
DMRT, depths	ab	a	ab	abc	abc	bc	c
DMRT, fields	ab	a	a	d	cd	b	c
Cane 1							
Mean, g Al m^{-3}	290	360	440	320	220	90	80
DMRT, depths	abc	ab	a	ab	bc	c	c
DMRT, fields	ab	a	ab	cd	cd	b	c
Cane 2							
Mean, g Al m^{-3}	330	370	470	320	350	170	70
DMRT, depths	ab	ab	a	ab	ab	bc	c
DMRT, fields	ab	a	ab	cd	bcd	b	c
Rice							
Mean, g Al m^{-3}	370	470	470	380	240	620	910
DMRT, depths	c	bc	bc	c	c	b	a
DMRT, fields	ab	a	ab	bcd	cd	a	a

Table A-21-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, g Al m^{-3}	520	580	640	640	740	630	440
DMRT, depths	ab	ab	ab	ab	a	ab	b
DMRT, fields	a	a	a	a	a	a	b
				Horticulture			
Mean, g Al m^{-3}	350	400	460	570	660	570	490
DMRT, depths	b	b	ab	ab	a	ab	ab
DMRT, fields	ab	a	ab	ab	a	a	b
				Vegetable 1			
Mean, g Al m^{-3}	430	470	500	530	520	260	150
DMRT, depths	ab	ab	a	a	a	bc	c
DMRT, fields	ab	a	ab	abc	ab	b	c
				Vegetable 2			
Mean, g Al m^{-3}	380	420	450	520	410	90	280
DMRT, depths	ab	ab	ab	a	ab	c	bc
DMRT, fields	ab	a	ab	abc	bc	b	bc

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-22. Iron extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, kg Fe m^{-3}	3.09	4.46	4.27	2.51	1.96	1.55	1.67
DMRT, depths	b	a	a	bc	bc	c	c
DMRT, fields	a	a	bc	e	e	c	b
Pasture 2							
Mean, kg Fe m^{-3}	3.47	4.48	5.19	3.72	2.82	2.05	1.40
DMRT, depths	bc	ab	a	bc	cd	de	e
DMRT, fields	a	a	ab	abcde	de	bc	b
Pasture 3							
Mean, kg Fe m^{-3}	3.24	4.34	5.64	3.24	2.26	1.52	1.10
DMRT, depths	bc	b	a	bc	cd	d	d
DMRT, fields	a	a	a	de	e	c	b
Virgin							
Mean, kg Fe m^{-3}	4.07	4.32	3.65	2.56	2.17	1.70	1.04
DMRT, depths	a	a	ab	bc	cd	cd	d
DMRT, fields	a	a	c	e	e	bc	b
Cane 1							
Mean, kg Fe m^{-3}	3.00	3.68	4.34	3.40	2.40	1.30	0.74
DMRT, depths	bc	ab	a	abc	cd	de	e
DMET, fields	a	a	abc	cde	e	c	b
Cane 2							
Mean, kg Fe m^{-3}	3.63	4.08	4.63	3.78	3.77	2.20	0.97
DMRT, depths	a	a	a	a	a	b	c
DMRT, fields	a	a	abc	abcde	cd	bc	b
Rice							
Mean, kg Fe m^{-3}	3.55	4.15	4.63	3.50	2.55	1.35	1.55
DMRT, depths	ab	a	a	ab	bc	c	c
DMRT, fields	a	a	abc	bcde	de	c	b

Table A-22-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, kg Fe m^{-3}	3.71	4.18	4.63	4.87	5.51	4.92	3.45
DMRT, depths	bc	bc	abc	ab	a	ab	c
DMRT, fields	a	a	abc	a	a	a	a
				Horticulture			
Mean, kg Fe m^{-3}	2.79	3.27	3.74	4.48	5.28	4.83	3.53
DMRT, depths	d	cd	bcd	abc	a	ab	cd
DMRT, fields	a	a	c	abcd	ab	a	a
				Vegetable 1			
Mean, kg Fe m^{-3}	3.54	3.88	4.19	4.63	4.39	2.93	1.35
DMRT, depths	ab	ab	ab	a	a	b	c
DMRT, fields	a	a	bc	abc	abc	b	b
				Vegetable 2			
Mean, kg Fe m^{-3}	3.45	3.88	4.30	4.78	4.14	1.85	1.65
DMRT, depths	b	ab	ab	a	ab	c	c
DMRT, fields	a	a	abc	ab	bc	bc	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-23. Copper extracted by hot 0.1N HCl from Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g Cu m^{-3}	5.0	4.9	2.2	0.96	0.45	0.51	0.10
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	bc	bc	c	c	c	b
				Pasture 2			
Mean, g Cu m^{-3}	9.9	3.3	1.8	0.43	0.35	0.12	0.09
DMRT, depths	a	b	b	b	b	b	b
DMRT, fields	b	bc	bc	c	c	c	b
				Pasture 3			
Mean, g Cu m^{-3}	17	13	4.9	0.65	0.41	0.16	0.07
DMRT, depths	a	a	b	b	b	b	b
DMRT, fields	a	a	abc	c	c	c	b
				Virgin			
Mean, g Cu m^{-3}	0.19	0.34	0	0.11	0.11	0	0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	c	c	c	c	c	b
				Cane 1			
Mean, g Cu m^{-3}	2.1	2.5	2.3	1.6	1.1	0.53	0.17
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	c	bc	bc	c	c	b
				Cane 2			
Mean, g Cu m^{-3}	1.6	2.3	2.7	1.8	1.7	0.58	0.24
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	c	bc	bc	bc	c	b
				Rice			
Mean, g Cu m^{-3}	1.3	1.8	1.7	1.3	0.71	0.09	0.19
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	c	bc	bc	c	c	b

Table A-23-continued.

Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
	Depth sampled, m						
				Fallow			
Mean, g Cu m^{-3}	5.1	5.5	6.1	6.2	6.5	5.6	3.0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	bc	ab	ab	b	ab	ab
				Horticulture			
Mean, g Cu m^{-3}	6.9	7.9	8.8	10	11	10	5.8
DMRT, depths	ab	ab	ab	ab	a	ab	b
DMRT, fields	bc	b	a	a	a	a	a
				Vegetable 1			
Mean, g Cu m^{-3}	2.3	2.6	2.8	3.2	3.0	1.6	0.46
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	c	bc	bc	bc	bc	b
				Vegetable 2			
Mean, g Cu m^{-3}	2.5	2.8	3.1	3.2	2.5	0.11	0.10
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	c	bc	bc	bc	c	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-24. Total P after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g P m^{-3}	736	795	463	190	129	102	72.9
DMRT, depths	a	a	b	c	c	c	c
DMRT, fields	a	ab	bcd	de	c	c	b
				Pasture 2			
Mean, g P m^{-3}	814	834	596	262	186	127	101
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	a	a	abc	cde	c	c	b
				Pasture 3			
Mean, g P m^{-3}	803	879	662	235	141	85.0	84.4
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	a	a	ab	cde	c	c	b
				Virgin			
Mean, g P m^{-3}	298	290	222	151	124	94.4	54.9
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	d	d	e	c	c	b
				Cane 1			
Mean, g P m^{-3}	318	309	337	234	178	82.5	45.5
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	d	cd	cde	c	c	b
				Cane 2			
Mean, g P m^{-3}	289	343	378	278	273	138	47.4
DMRT, depths	ab	a	a	ab	ab	ab	b
DMRT, fields	c	d	bcd	cde	bc	c	b
				Rice			
Mean, g P m^{-3}	406	526	546	464	261	95.4	110
DMRT, depths	a	a	a	a	ab	b	b
DMRT, fields	bc	bcd	abc	bcd	bc	c	b

Table A-24-continued.

Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, g P m^{-3}	391	430	467	498	540	460	278
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	cd	bcd	bc	b	b	b
				Horticulture			
Mean, g P m^{-3}	610	696	781	841	880	829	567
DMRT, depths	ab	ab	ab	ab	a	ab	b
DMRT, fields	ab	abc	a	a	a	a	a
				Vegetable 1			
Mean, g P m^{-3}	447	485	523	566	476	230	77.2
DMRT, depths	ab	ab	a	a	ab	bc	c
DMRT, fields	bc	cd	abc	b	b	bc	b
				Vegetable 2			
Mean, g P m^{-3}	350	403	456	462	398	79.0	59.4
DMRT, depths	a	a	a	a	a	b	b
DMRT, fields	bc	d	bcd	bcd	bc	c	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-25. Total organic P after ashing of Pahokee muck from 11 fields sampled at seven depths.

Factor†	Depth sampled, m						
	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, g P m^{-3}	338	353	285	132	89.0	62.9	46.4
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	ab	ab	ab	de	e	b	b
Pasture 2							
Mean, g P m^{-3}	369	370	318	193	149	100	76.9
DMRT, depths	a	a	a	b	bc	bc	c
DMRT, fields	a	a	ab	bcde	cde	b	b
Pasture 3							
Mean, g P m^{-3}	362	371	358	157	112	67.6	59.6
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	a	a	a	cde	de	b	b
Virgin							
Mean, g P m^{-3}	227	220	168	116	96.2	68.2	34.5
DMRT, depths	a	a	ab	bc	bc	bc	c
DMRT, fields	c	cd	c	e	de	b	b
Cane 1							
Mean, g P m^{-3}	194	184	247	193	144	58.2	32.2
DMRT, depths	ab	ab	a	ab	bc	cd	d
DMRT, fields	c	d	bc	bcde	cde	b	b
Cane 2							
Mean, g P m^{-3}	203	234	223	197	200	106	30.2
DMRT, depths	ab	a	a	ab	ab	bc	c
DMRT, fields	c	cd	bc	bcde	bcd	b	b
Rice							
Mean, g P m^{-3}	194	262	231	224	131	50.2	53.7
DMRT, depths	ab	a	a	ab	bc	c	c
DMRT, fields	c	bcd	bc	bcd	cde	b	b

Table A-25-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Fallow							
Mean, g P m^{-3}	263	294	325	350	373	324	187
DMRT, depths	bc	ab	ab	ab	a	ab	c
DMRT, fields	bc	abc	ab	a	a	a	a
Horticulture							
Mean, g P m^{-3}	166	197	227	272	260	269	178
DMRT, depths	b	ab	ab	a	ab	ab	ab
DMRT, fields	c	cd	bc	ab	a	a	a
Vegetable 1							
Mean, g P m^{-3}	205	223	241	255	199	133	46.8
DMRT, depths	ab	ab	a	a	ab	bc	c
DMRT, feilds	c	cd	bc	abc	bcd	b	b
Vegetable 2							
Mean, g P m^{-3}	213	233	254	249	230	51.2	39.7
DMRT, depths	a	a	a	a	a	b	b
DMRT, fields	c	cd	bc	bc	bc	b	b

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† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-26. Calcium after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, kg Ca m^{-3}	11.1	14.5	16.9	11.5	11.5	10.6	9.07
DMRT, depths	bc	ab	a	bc	bc	bc	c
DMRT, fields	cd	bc	bcd	e	d	de	bc
				Pasture 2			
Mean, kg Ca m^{-3}	10.8	13.5	14.9	14.1	13.2	12.5	11.4
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	bc	cd	de	cd	cd	b
				Pasture 3			
Mean, kg Ca m^{-3}	7.98	10.5	12.8	10.1	9.79	7.93	7.70
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	c	d	e	d	de	bc
				Virgin			
Mean, kg Ca m^{-3}	13.0	13.9	12.9	10.6	10.6	10.7	8.22
DMRT, depths	ab	a	ab	ab	ab	ab	b
DMRT, fields	abcd	bc	d	e	d	de	bc
				Cane 1			
Mean, kg Ca m^{-3}	12.0	15.0	17.5	14.6	12.1	9.18	5.80
DMRT, depths	bc	ab	a	ab	bc	cd	d
DMRT, fields	bcd	bc	bcd	cde	cd	de	c
				Cane 2			
Mean, kg Ca m^{-3}	16.9	18.7	20.5	16.9	17.0	11.5	6.41
DMRT, depths	a	a	a	a	a	b	c
DMRT, fields	ab	ab	ab	bcd	bc	cd	bc
				Rice			
Mean, kg Ca m^{-3}	18.0	21.9	23.7	17.5	12.8	5.74	6.09
DMRT, depths	b	ab	a	bc	c	d	d
DMRT, fields	a	a	a	bcd	cd	e	bc

Table A-26-continued.

Factor†	Depth sampled, m 0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, kg Ca m^{-3}	14.1	15.9	17.5	19.4	22.3	21.0	16.7
DMRT, depths	c	bc	abc	ab	a	ab	bc
DMRT, fields	abc	b	bcd	abc	a	ab	a
				Horticulture			
Mean, kg Ca m^{-3}	14.3	16.5	18.7	24.3	25.1	23.3	19.2
DMRT, depths	c	c	bc	a	a	ab	bc
DMRT, fields	abc	b	abc	a	a	a	a
				Vegetable 1			
Mean, kg Ca m^{-3}	17.0	18.2	19.4	23.0	22.4	16.3	10.7
DMRT, depths	b	ab	ab	a	a	b	c
DMRT, fields	ab	ab	abc	a	a	bc	bc
				Vegetable 2			
Mean, kg Ca m^{-3}	15.5	17.8	20.2	21.6	20.3	10.8	7.74
DMRT, depths	bc	ab	ab	a	ab	cd	d
DMRT, fields	abc	ab	abc	ab	ab	de	bc

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-27. Magnesium after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, kg Mg m^{-3}	1.0	1.8	1.4	0.67	0.57	0.58	0.56
DMRT, depths	bc	a	ab	c	c	c	c
DMRT, fields	bc	ab	bc	cd	d	cd	cd
Pasture 2							
Mean, kg Mg m^{-3}	1.4	1.6	1.7	1.6	0.87	0.52	0.52
DMRT, depths	a	a	a	a	b	b	b
DMRT, fields	ab	abc	bc	b	bcd	d	cd
Pasture 3							
Mean, kg Mg m^{-3}	0.88	0.97	1.4	1.4	0.77	0.39	0.37
DMRT, depths	abc	ab	a	a	bc	c	c
DMRT, fields	bc	de	bc	b	cd	d	d
Virgin							
Mean, kg Mg m^{-3}	1.0	0.97	0.74	0.50	0.46	0.42	0.35
DMRT, depths	a	ab	abc	abc	abc	bc	c
DMRT, fields	bc	de	d	d	d	d	d
Cane 1							
Mean, kg Mg m^{-3}	0.62	0.65	0.74	0.58	0.49	0.42	0.33
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	c	e	d	cd	d	d	d
Cane 2							
Mean, kg Mg m^{-3}	1.2	1.3	1.5	1.1	1.2	0.82	0.45
DMRT, depths	ab	ab	a	ab	ab	bc	c
DMRT, fields	b	bcd	bc	bc	bc	bcd	cd
Rice							
Mean, kg Mg m^{-3}	1.9	2.1	1.9	1.2	0.90	0.86	1.3
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	a	a	b	b	bcd	bcd	b

Table A-27-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, kg Mg m^{-3}	0.94	1.1	1.2	1.3	1.4	1.3	0.96
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	bc	cde	cd	b	b	b	bc
				Horticulture			
Mean, kg Mg m^{-3}	1.8	2.0	2.4	2.9	3.0	2.8	2.4
DMRT, depths	d	cd	bc	ab	a	ab	bc
DMRT, fields	a	a	a	a	a	a	a
				Vegetable 1			
Mean, kg Mg m^{-3}	1.1	1.2	1.2	1.4	1.4	1.1	0.75
DMRT, depths	ab	ab	ab	a	a	ab	b
DMRT, fields	bc	cde	cd	b	b	bc	cd
				Vegetable 2			
Mean, kg Mg m^{-3}	0.99	1.2	1.3	1.4	1.3	0.64	0.71
DMRT, depths	abc	ab	a	a	a	c	c
DMRT, fields	bc	cde	c	b	bc	cd	cd

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-28. Potassium after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, g K m^{-3}	350	560	380	180	160	120	100
DMRT, depths	b	a	b	c	c	c	c
DMRT, fields	ab	a	ab	abc	ab	a	a
				Pasture 2			
Mean, g K m^{-3}	420	450	450	320	200	79	72
DMRT, depths	a	a	a	ab	bc	c	c
DMRT, fields	a	a	a	a	ab	a	a
				Pasture 3			
Mean, g K m^{-3}	250	230	220	190	78	29	23
DMRT, depths	a	ab	ab	ab	bc	c	c
DMRT, fields	bc	b	c	abc	ab	a	a
				Virgin			
Mean, g K m^{-3}	150	120	100	58	42	27	16
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	b	c	bc	b	a	a
				Cane 1			
Mean, g K m^{-3}	170	170	130	67	40	16	9.0
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	b	c	bc	b	a	a
				Cane 2			
Mean, g K m^{-3}	63	61	71	52	50	23	10
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	c	bc	b	a	a
				Rice			
Mean, g K m^{-3}	92	100	110	86	58	88	120
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	b	c	bc	b	a	a

Table A-28-continued.

Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
	Depth sampled, m						
				Fallow			
Mean, g K m^{-3}	73	84	93	120	130	110	70
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	d	b	c	bc	ab	a	a
				Horticulture			
Mean, g K m^{-3}	100	130	150	210	240	180	140
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	b	c	abc	a	a	a
				Vegetable 1			
Mean, g K m^{-3}	200	220	230	230	180	78	28
DMRT, depths	a	a	a	a	ab	ab	b
DMRT, fields	bcd	b	bc	ab	ab	a	a
				Vegetable 2			
Mean, g K m^{-3}	110	120	140	120	86	21	44
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	cd	b	c	bc	ab	a	a

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-29. Aluminum after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, kg Al m^{-3}	1.4	2.2	2.0	0.77	0.49	0.37	0.24
DMRT, depths	bc	a	ab	cd	d	d	d
DMRT, fields	a	a	ab	d	e	c	d
Pasture 2							
Mean, kg Al m^{-3}	1.5	1.9	2.4	2.5	1.4	0.65	0.53
DMRT, depths	b	ab	a	a	b	c	c
DRMT, fields	a	ab	a	a	bcd	c	d
Pasture 3							
Mean, kg Al m^{-3}	0.89	1.1	2.0	2.3	1.1	0.37	0.28
DMRT, depths	bc	b	a	a	b	bc	c
DMRT, fields	a	b	ab	a	cde	c	d
Virgin							
Mean, kg Al m^{-3}	1.3	1.4	1.3	0.91	0.70	0.52	0.27
DMRT, depths	ab	a	ab	abc	abc	bc	c
DMRT, fields	a	ab	b	cd	de	c	d
Cane 1							
Mean, kg Al m^{-3}	0.95	1.2	1.3	1.0	0.70	0.34	0.20
DMRT, depths	ab	a	a	ab	ab	b	b
DMRT, fields	a	b	b	bcd	de	c	d
Cane 2							
Mean, kg Al m^{-3}	1.2	1.4	1.6	1.2	1.3	0.57	0.23
DMRT, depths	ab	a	a	ab	ab	bc	c
DMRT, fields	a	ab	ab	bcd	bcde	c	d
Rice							
Mean, kg Al m^{-3}	1.4	1.7	1.8	1.3	0.95	1.6	2.3
DMRT, depths	bc	abc	ab	bc	c	abc	a
DMRT, fields	a	ab	ab	bcd	cde	ab	a

Table A-29-continued.

	Depth sampled, m						
Factor[†]	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, kg Al m^{-3}	1.6	1.8	2.0	2.2	2.5	2.2	1.4
DMRT, depths	b	ab	ab	ab	a	ab	b
DMRT, fields	a	ab	ab	a	a	a	bc
				Horticulture			
Mean, kg Al m^{-3}	1.2	1.4	1.6	1.8	2.1	1.9	1.6
DMRT, depths	b	ab	ab	ab	a	ab	ab
DMRT, fields	a	ab	ab	ab	ab	a	ab
				Vegetable 1			
Mean, kg Al m^{-3}	1.3	1.4	1.5	1.7	1.6	0.88	0.36
DMRT, depths	a	a	a	a	a	ab	a
DMRT, fields	a	ab	b	abc	bc	bc	d
				Vegetable 2			
Mean, kg Al m^{-3}	1.3	1.5	1.6	1.8	1.5	0.30	0.83
DMRT, depths	ab	ab	ab	a	ab	c	bc
DMRT, fields	a	ab	ab	ab	bcd	c	cd

[†] Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-30. Iron after ashing of Pahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Pasture 1			
Mean, kg Fe m^{-3}	3.2	4.4	4.3	2.4	1.8	1.4	1.5
DMRT, depths	ab	a	a	bc	c	c	c
DMRT, fields	a	a	bc	c	d	bc	b
				Pasture 2			
Mean, kg Fe m^{-3}	3.2	4.3	5.0	3.8	2.6	1.9	1.3
DMRT, depths	bc	ab	a	abc	cd	de	e
DMRT, fields	a	a	ab	ab	cd	bc	b
				Pasture 3			
Mean, kg Fe m^{-3}	2.9	4.1	5.6	3.7	2.3	1.2	1.2
DMRT, depths	bc	b	a	b	cd	d	d
DMRT, fields	a	a	a	ab	cd	c	b
				Virgin			
Mean, kg Fe m^{-3}	3.9	4.2	3.4	2.4	2.0	1.5	0.87
DMRT, depths	a	a	ab	bc	cd	cd	d
DMRT, fields	a	a	c	c	d	bc	b
				Cane 1			
Mean, kg Fe m^{-3}	2.7	3.4	4.0	3.0	2.3	1.2	0.64
DMRT, depths	b	ab	a	ab	bc	cd	d
DMRT, fields	a	a	bc	bc	cd	c	b
				Cane 2			
Mean, kg Fe m^{-3}	3.3	3.8	4.2	3.5	3.5	2.0	0.82
DMRT, depths	a	a	a	a	a	a	c
DMRT, fields	a	a	bc	abc	bc	bc	b
				Rice			
Mean, kg Fe m^{-3}	3.4	4.1	4.4	3.4	2.5	1.4	1.8
DMRT, depths	ab	a	a	ab	bc	c	c
DMRT, fields	a	a	abc	abc	cd	bc	b

Table A-30-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, kg Fe m^{-3}	3.5	3.9	4.3	3.7	5.4	4.5	3.2
DMRT, depths	bc	bc	abc	ab	a	ab	c
DMRT, fields	a	a	bc	a	a	a	a
				Horticulture			
Mean, kg Fe m^{-3}	2.6	3.1	3.5	4.1	4.7	4.3	3.4
DMRT, depths	c	bc	abc	ab	a	ab	bc
DMRT, fields	a	a	c	ab	ab	a	a
				Vegetable 1			
Mean, kg Fe m^{-3}	3.1	3.4	3.7	4.1	4.0	2.6	1.1
DMRT, depths	ab	ab	ab	a	a	b	c
DMRT, fields	a	a	bc	ab	b	b	b
				Vegetable 2			
Mean, kg Fe m^{-3}	3.5	4.0	4.5	4.7	4.2	1.8	1.6
DMRT, depths	a	a	a	a	a	b	b
DMRT, fields	a	a	abc	a	ab	bc	b

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-31. Copper after ashing of Phahokee muck from 11 fields sampled at seven depths.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
Pasture 1							
Mean, g Cu m^{-3}	29	38	24	7.8	3.5	2.6	2.4
DMRT, depths	a	a	a	b	b	b	b
DMRT, fields	bcd	b	cd	c	d	c	c
Pasture 2							
Mean, g Cu m^{-3}	34	32	19	5.5	3.1	2.4	1.9
DMRT, depths	a	a	ab	bc	c	c	c
DMRT, fields	bc	bc	cd	c	d	c	c
Pasture 3							
Mean, g Cu m^{-3}	61	74	32	8.0	4.1	2.2	2.1
DMRT, depths	a	a	b	c	c	c	c
DMRT, fields	a	a	bc	c	d	c	c
Virgin							
Mean, g Cu m^{-3}	3.0	2.9	2.3	1.7	1.4	1.1	0.70
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	e	e	e	c	d	c	c
Cane 1							
Mean, g Cu m^{-3}	16	21	21	14	9.2	3.7	1.7
DMRT, depths	ab	a	a	ab	ab	b	b
DMRT, fields	de	cd	cd	bc	cd	c	c
Cane 2							
Mean, g Cu m^{-3}	13	18	21	14	9.2	3.7	1.7
DMRT, depths	ab	a	a	ab	ab	b	b
DMRT, fields	de	cde	cd	bc	cd	c	c
Rice							
Mean, g Cu m^{-3}	13	13	15	10	6.8	1.5	1.6
DMRT, depths	a	a	a	a	a	a	a
DMRT, fields	de	de	de	bc	cd	c	c

Table A-31-continued.

	Depth sampled, m						
Factor†	0 to 0.05	0.05 to 0.10	0.10 to 0.15	0.15 to 0.22	0.22 to 0.29	0.29 to 0.36	0.36 to 0.43
				Fallow			
Mean, g Cu m^{-3}	33	38	41	45	50	41	25
DMRT, depths	bc	abc	abc	ab	a	abc	c
DMRT, fields	bc	b	ab	a	b	b	b
				Horticulture			
Mean, g Cu m^{-3}	40	45	51	59	68	62	45
DMRT, depths	d	cd	bcd	abc	a	ab	cd
DMRT, fields	b	b	d	a	a	a	a
				Vegetable 1			
Mean, g Cu m^{-3}	19	21	23	25	22	11	2.2
DMRT, depths	a	a	a	a	a	ab	b
DMRT, fields	cde	cd	cd	b	c	c	c
				Vegetable 2			
Mean, g Cu m^{-3}	19	22	25	26	22	2.4	1.6
DMRT, depths	a	a	a	a	a	b	b
DMRT, fields	cde	cd	cd	b	c	c	c

† Horizontal means (depths) or vertical means (fields) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-32. Analysis of variance for various determinations on Pahokee muck from 11 fields sampled at seven depths.

Model fit[†]			Factors[‡]		
r^2	α	CV	Fields (F)	Depths (D)	FxD
		Oven-dry bulk density, Mg m^{-3}			
0.90	***	14	NA	NA	***
		pH of soil paste			
0.90	***	5	***	***	NS
		Ash, % (w/w)			
0.84	***	9	NA	NA	***
		Ash, kg m^{-3}			
0.89	***	17	NA	NA	***
		Field moisture, % (w/w)			
0.93	***	19	NA	NA	**
		Field moisture, % (v/v)			
0.93	***	9	NA	NA	***

† r^2, α, and CV are coefficent of determination, level of significance, and coefficient of variation, respectively.

‡ NA, NS, **, and *** are not applicable, not significant, significant at the 1% and 0.1% levels, respectively.

Table A-33. Analysis of variance for various cations in double acid, hot 0.1N HCl, and after ashing of Pahokee muck from 11 fields sampled at seven depths.

Model fit†			Factors‡		
r^2	α	CV	Fields (F)	Depths (D)	FxD
		Ca by double acid, kg m^{-3}			
0.90	***	15	NA	NA	***
		Ca by hot 0.1N HCl, kg m^{-3}			
0.90	***	15	NA	NA	***
		Mg by ashing, kg m^{-3}			
0.92	***	22	NA	NA	***
		Al by ashing, kg m^{-3}			
0.84	***	29	NA	NA	***
		Fe by double acid, g m^{-3}			
0.81	***	49	NA	NA	**
		Fe by hot 0.1N HCl,, kg m^{-3}			
0.90	***	18	NA	NA	***
		Cu by double acid, g m^{-3}			
0.83	***	74	NA	NA	***
		Cu by hot 0.1N HCl, g m^{-3}			
0.82	***	77	NA	NA	***
		Cu by ashing, g m^{-3}			
0.93	***	37	NA	NA	***
		K by ashing, g m^{-3}			
0.81	***	55	NA	NA	*

† r^2, α, and CV are coefficient of determination, level of significance, and coefficient of variation, respectively.

‡ NA, *, **, and *** are not applicable and significant at the 5, 1, and 0.1% levels, respectively.

Table A-34. Analysis of variance for proportion of water-extractable elements compared to those by double acid, hot 0.1N HCl, and total in ashed samples of Pahokee muck from seven fields sampled at seven depths.

Model fit†			Factors‡		
r^2	∝	CV	Fields (F)	Depths (D)	FxD
			P (W) / P (DA)		
0.99	***	30	NA	NA	***
			P (W) / P (HCl)		
0.96	***	19	NA	NA	***
			P (W) / P (Ash)		
0.86	***	26	NA	NA	*
			Ca (W) / Ca (DA)		
0.95	***	22	NA	NA	**
			Ca (W) / Ca (HCl)		
0.94	***	24	NA	NA	**
			Mg (W) / Mg (Ash)		
0.89	***	29	***	***	NS
			K (W) / K (Ash)		
0.76	***	52	***	NS	NS
			Fe (W) / Fe (DA)		
0.85	***	50	***	NS	NS
			Fe (W) / Fe (HCl)		
0.83	***	49	***	**	NS

† r^2, ∝, and CV are coefficient of determination, level of significance, and coefficient of variation, respectively.

‡ NA, NS, *, **, and *** are not applicable, not significant, and significant at the 5, 1, and 0.1% levels, respectively.

Table A-35. Analysis of variance for proportion of cations extracted by different methods from Pahokee muck from 11 fields sampled at seven depths.

Model fit†			Factors‡		
r^2	∝	CV	Fields (F)	Depths (D)	FxD
		Ca by double acid / Ca by hot 0.1N HCl			
0.52	NS	4	NA	NA	NA
		Ca by ashing / Ca by hot 0.1N HCl			
0.54	NS	5	NA	NA	NA
		Al by double acid / Al by hot 0.1N HCl			
0.77	***	18	NA	NA	**
		Al by double acid / Al by ashing			
0.72	***	18	***	***	NS
		Al by hot 0.1N HCl / Al by ashing			
0.70	***	11	***	***	NS
		Fe by double acid / Fe by hot 0.1N HCl			
0.85	***	37	NA	NA	*
		Fe by ashing / Fe by hot 0.1N HCl			
0.66	**	7	***	*	NS
		Cu by double acid / Cu by ashing			
0.62	*	72	***	NS	NS
		Cu by hot 0.1N HCl / Cu by ashing			
0.62	**	49	***	*	NS

† r^2, ∝, and CV are coefficient of determination, level of significance, and coefficient of variation, respectively.

‡ NA, NS, *, **, and *** are not applicable, not significant, and significant at the 5, 1, and 0.1% levels, respectively.

Table A-36. Analysis of the significant sampling time x P-rate interaction on the rate of carbon dioxide production from vegetable soil incubated with corn stover at four rates of added P.

Factor†	P rate, mg P kg^{-1}			
	0	20	40	80
		2 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	395	419	451	410
DMRT, P rate	b	b	a	b
DMRT, sampling time	c	c	c	c
		3 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	496	555	573	537
DMRT, P rate	c	ab	a	b
DMRT, sampling time	b	a	a	b
		4 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	543	558	593	543
DMRT, P rate	b	b	a	b
DMRT, sampling time	a	a	a	a
		5 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	491	486	512	451
DMRT, P rate	a	a	a	b
DMRT, sampling time	b	b	b	b
		7 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	331	342	343	310
DMRT, P rate	ab	a	a	b
DMRT, sampling time	d	d	d	d
		10 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	176	174	177	165
DMRT, P rate	a	a	a	a
DMRT, sampling time	e	e	e	e
		14 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	108	109	109	104
DMRT, P rate	a	a	a	a
DMRT, sampling time	f	f	f	f

Table A-36-continued.

Factor†	P rate, mg P kg^{-1} 0	20	40	80
		20 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	71	71	68	72
DMRT, P rate	a	a	a	a
DMRT, sampling time	g	g	g	g
		29 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	57	56	53	56
DMRT, P rate	a	a	a	a
DMRT, sampling time	g	g	g	g
		47 days		
Mean, mg CO_2-C kg^{-1} day^{-1}	31	29	28	30
DMRT, P rate	a	a	a	a
DMRT, sampling time	h	h	h	h

† Horizontal means (P rate) or vertical means (sampling time) not followed by the same letter are significantly different at the 5% level by Duncan's Multiple Range Test (DMRT).

Table A-37. Analysis of differences in the rate of carbon dioxide production from soils incubated with corn stover at four rates of added P for each sampling time.

	P rate, mg P kg^{-1}			
Soil†	0	20	40	80
	mg CO_2-C kg^{-1} day^{-1}			
2 days				
Vegetable	395 b	419 a	451 a	410 a
Virgin	439 a	428 a	448 a	432 a
3 days				
Vegetable	496 b	555 a	573 b	537 b
Virgin	614 a	563 a	614 a	571 a
4 days				
Vegetable	543 a	558 a	593 a	543 a
Virgin	431 b	413 b	425 b	403 b
5 days				
Vegetable	491 a	486 a	512 a	451 a
Virgin	307 b	316 b	302 b	292 b
7 days				
Vegetable	331 a	342 a	343 a	310 a
Virgin	245 b	240 b	233 b	210 b
10 days				
Vegetable	178 a	174 a	177 a	165 a
Virgin	150 b	149 a	133 b	125 b
14 days				
Vegetable	108 a	109 a	109 a	104 a
Virgin	94 a	96 a	85 a	83 a
20 days				
Vegetable	71 a	72 a	68 a	72 a
Virgin	68 a	68 a	60 a	60 a

Table A-37-continued.

Soil†	P rate, mg P kg^{-1} 0	20	40	80
	mg CO_2-C kg^{-1} day^{-1}			
		29 days		
Vegetable	57 a	56 a	53 a	56 a
Virgin	54 a	57 a	50 a	49 a
		47 days		
Vegetable	31 a	29 a	28 a	30 a
Virgin	31 a	31 a	29 a	28 a

† Vertical means at each sampling time not followed by the same letter are significantly different at the 5% level.

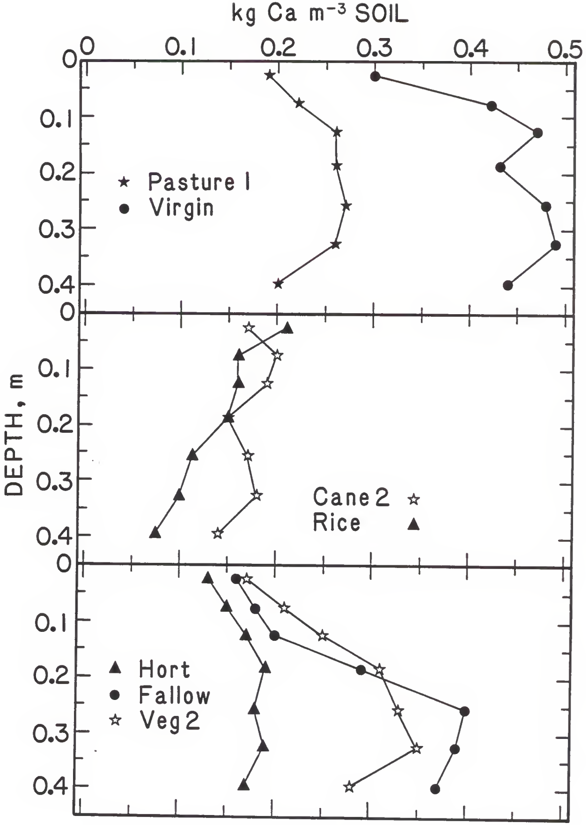

Fig. A-1. Calcium extracted by water from Pahokee muck from seven fields sampled at seven depths.

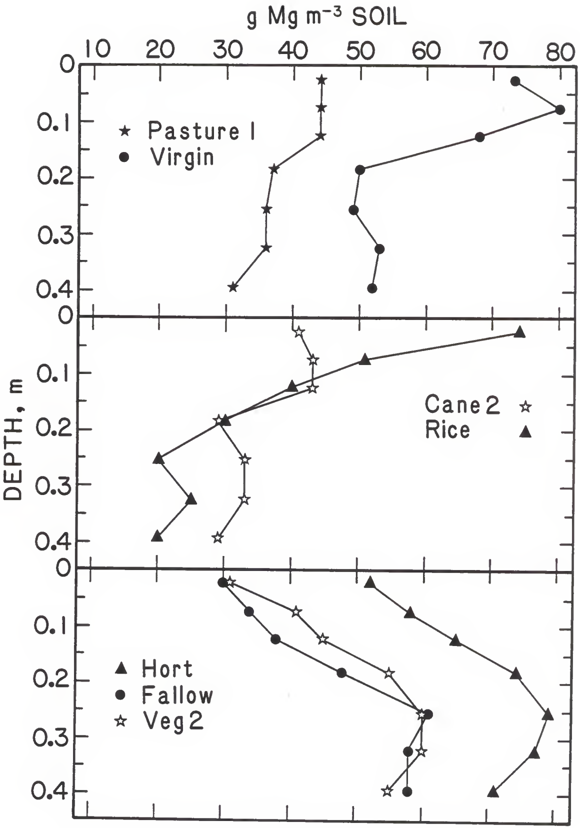

Fig. A-2. Magnesium extracted by water from Pahokee muck from seven fields sampled at seven depths.

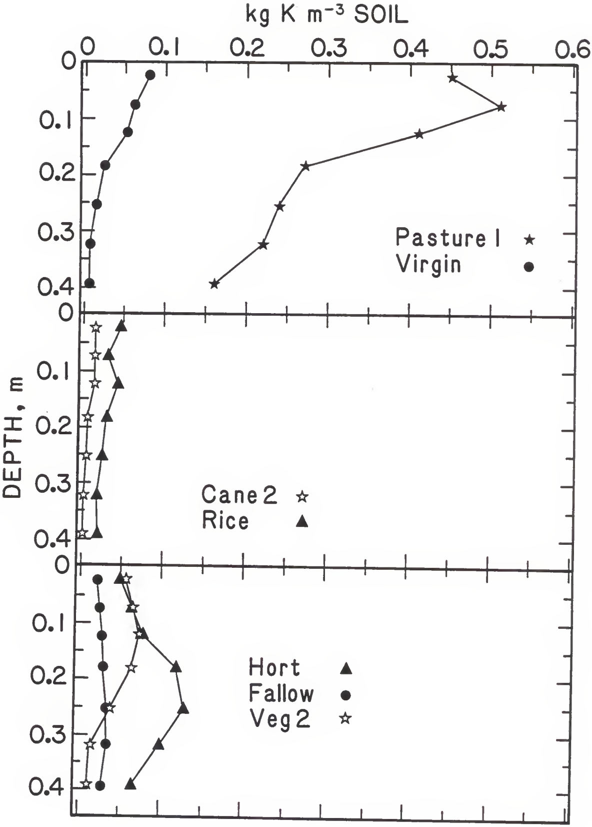

Fig. A-3. Potassium extracted by water from Pahokee muck from seven fields sampled at seven depths.

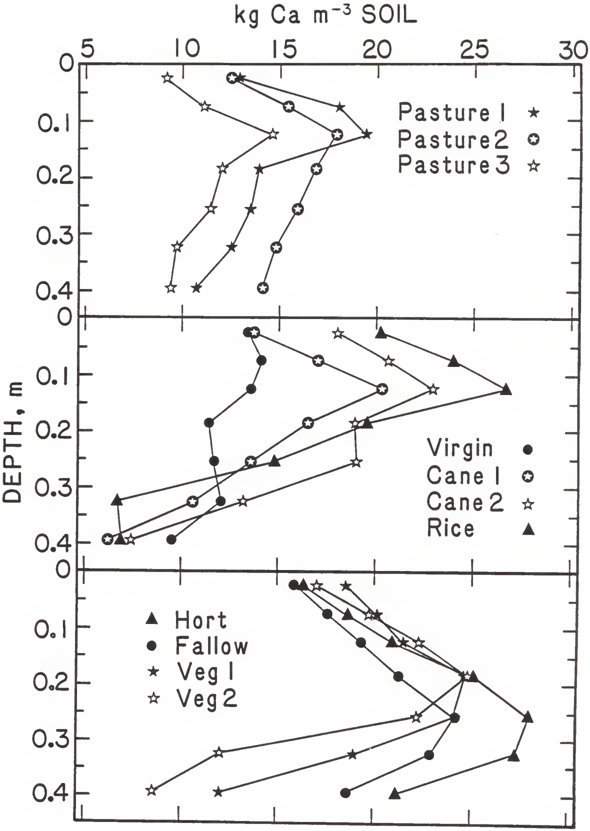

Fig. A-4. Calcium extracted by hot 0.1N HCL from Pahokee muck from seven fields sampled at seven depths.

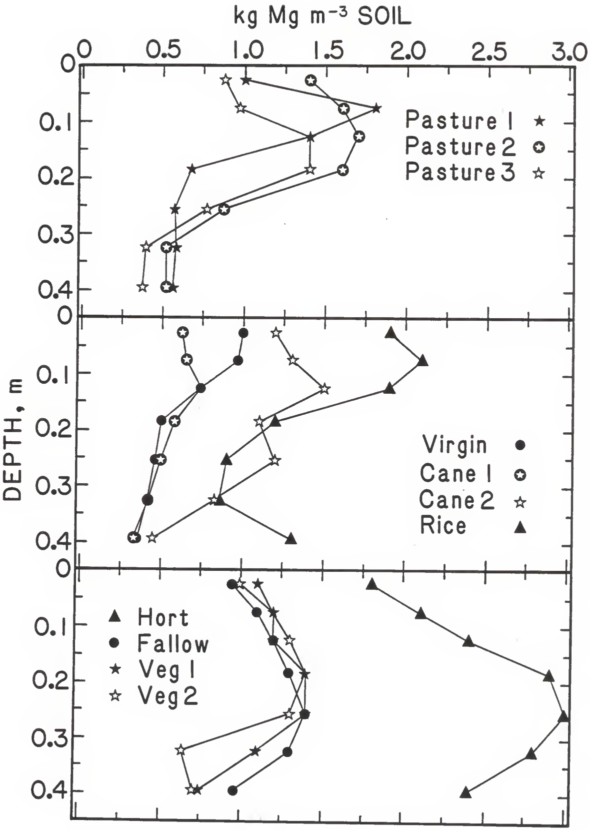

Fig. A-5. Magnesium after ashing of Pahokee muck from 11 fields sampled at seven depths.

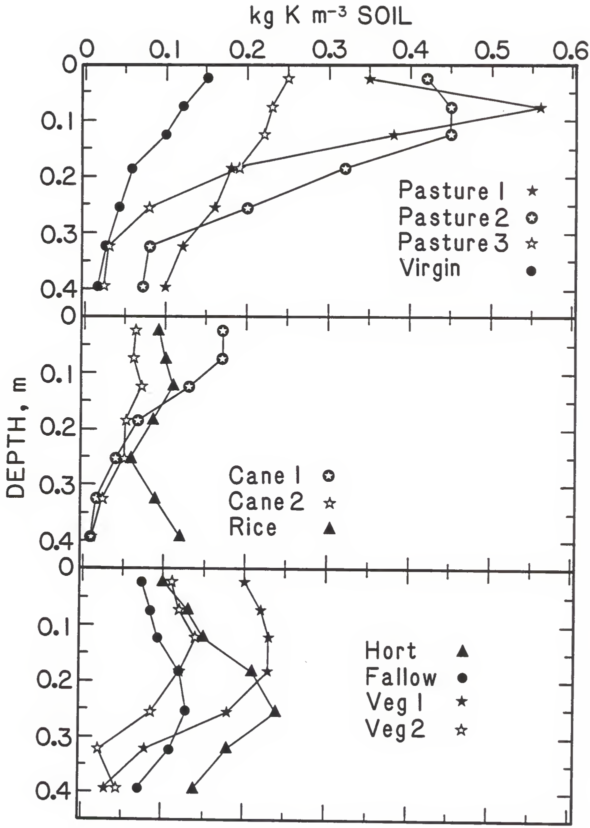

Fig. A-6. Potassium after ashing of Pahokee muck from 11 fields sampled at seven depths.

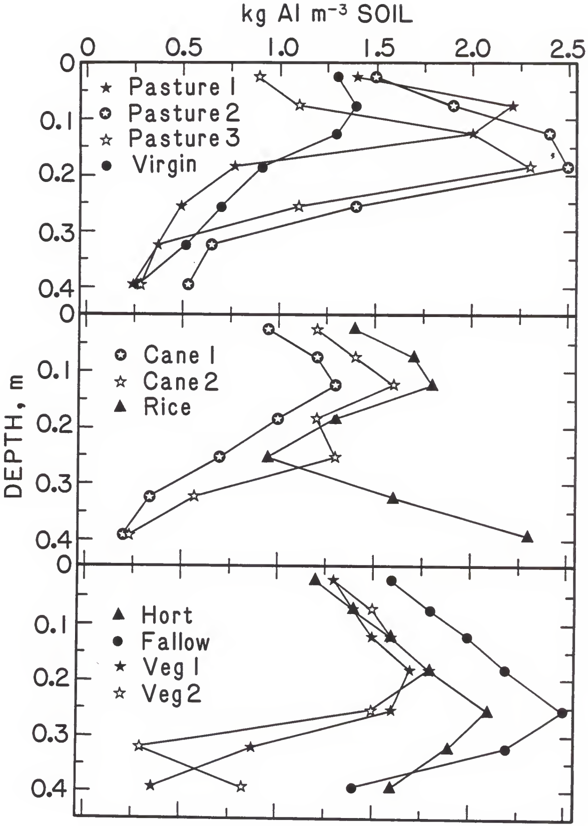

Fig. A-7. Aluminium after ashing of Pahokee muck from 11 fields sampled at seven depths.

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BIOGRAPHICAL SKETCH

Ian Keith Nicholson, son of Frederick and Shirley Nicholson, was born March 6, 1949, in Bath, England. He emigrated to Canada in August 1952 and became a Canadian citizen in October 1968. In June 1966, he graduated from Woodroffe High School, Ottawa, and entered the Honors Bachelor of Science program in biology at Carleton University, Ottawa, in September of that year.

After graduation in 1970, he was employed for six years, first at Statistics Canada and then at the Soil Research Institute, Agriculture Canada, in Ottawa, Ontario. He obtained his Master of Science degree in soil science at the University of Manitoba under Dr. C.M. Cho in August 1979. He moved to Gainesville, Florida, where he attended the University of Florida, working towards his Doctor of Philosophy in soil science under Dr. J.G.A. Fiskell.

He is a member of the Canadian Society of Soil Science, the Soil Science Society of America, the Phi Kappa Phi Honor Society, the Ottawa Field Naturalists' Club, the Federation of Ontario Naturalists, and the Canadian Nature Federation.

Ian Nicholson married Gillian Goodwin on May 20, 1977, and they have one daughter, Barbara Erin, born December 12, 1978.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John G.A. Fiskell
John G.A. Fiskell, Chairman
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Donald A. Graetz
Donald A. Graetz
Associate Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

David H Hubbell
David H. Hubbell
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Joh J McCreary
John J. McCreary
Assistant Professor of Environmental
Engineering Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

George H. Snyder
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Bob G. Volk

Bob G. Volk
Associate Professor of Soil Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Jack L. Fry

Dean, College of Agriculture

Dean for Graduate Studies and Research